PB-227 351

SURVEY OF FACILITIES USING LAND APPLICATION OF WASTEWATER

American Public Works Association

PREPARED FOR
Environmental Protection Agency

July 1973

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NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET

1. Report No.
EPA-430/9-73-006

2.

PB 227 351

4. Title and Subtitle
SURVEY OF FACILITIES USING LAND APPLICATION OF WASTEWATER

5. Report Date
July 1973

6.

7. Author(s)
Richard H. Sullivan:Morris M. Cohn: Samuel S. Baxter

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Research Foundation of American Public Works Association,
1313 East 60th Street, Chicago, Illinois 60637

10. Project/Task/Work Unit No.

11. Contract/Grant No.
68-01-0732

12. Sponsoring Organization Name and Address
OFFICE OF WATER PROGRAM OPERATIONS
ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

BL Seabrook

13. Type of Report & Period Covered
Final

14.

15. Supplementary Notes

16. Abstracts

See page iii of report

17. Key Words and Document Analysis. 17a. Descriptors

* Irrigation systems, * Design criteria, * Wastewater treatment, * Wastewater application, * Wastewater renovation, * Costs, * Groundwater recharge, * Public health, *Environmental effects, * Sewage treatment, * Industrial wastes, * Land application, * Land treatment, * Climatic zones, * Soil treatment, Reclaimed water, Wastewater disposal, Land disposal, History, Crops, Percolation, Management, Monitoring, Public Relations, Advanced waste treatment, Convential treatment, Cropland irrigation, Flood irrigation, Groundwater, Overland flow irrigation, Secondary treatment, Sewage farming, Spray irrigation, Spray run-off, Zero pollution.

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement
EPA Press Release available from EPA Press Office
Deister, 202-755-0344
SN 5501-00666

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
382

22. Price
$6.80

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

EPA–430/9-73-006
July 1973

SURVEY OF FACILITIES USING LAND APPLICATION OF WASTEWATER

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WASHINGTON, D.C. 20460

Available from SOD
GPO order number SN-5501 00666
PC $6.90

EPA Review Notice

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency.

the report presents

ABSTRACT

The American Public Works Association, in 1972, conducted a field survey of 100 facilities where land application of domestic or industrial wastewater effluents were applied to the land, as contrasted to the conventional method of discharging such effluents to receiving waters. In addition, an extensive bibliography was compiled (to be published separately); data were gathered from many other existing land application facilities across the country; determinations were made as to State regulations governing the use of land application facilities; and a survey was made of experience gained in many foreign countries.

The facilities surveyed were relatively large, with long-established operations in order that as many viable operating experiences as possible could be obtained. The surveyed land application facilities utilizing domestic wastewaters were predominantly located in the western and southwestern portions of the nation, while industrial facilities were generally sited in the northeastern section, because this is where the majority of such installations are in service.

Agricultural wastes facilities and evaporation-percolation or spray runoff type facilities were outside the scope of the investigation.

Ninty-nine tables and the collected data are presented. Photographs of representative facilities are used to illustrate land application practices.

The report is presented as fulfillment of Contract 68-01-0732 by the American Public Works Association, Chicago, Illinois.

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FOREWORD

The report which follows gives the result of an extensive study conducted by the APWA Research Foundation concerning the operation of facilities for the land application of domestic and industrial wastewaters. The Bibliography which was compiled for the report is being reproduced as a separate document which will be collated with the bibliographies prepared by other USEPA Contractors who are reporting on related phases of land application practices.

Through this report, the American Public Works Association has sought to bring the operating experience of major users of land application systems together in one usable document. This report is intended to provide basic information for the United States Environmental Protection Agency as it prepares guidelines for evaluation of this alternative means of wastewater treatment. The information in the report should be of value to State regulation agencies, local agencies and industries, consulting engineers, and citizens who are striving to evaluate the means that can be used to achieve the best practical technology for the management of wastewaters and effluents.

The Association is aware that in the minds of many persons land application of wastewaters has been discredited and is poorly considered. However, on the basis of the exhaustive study which was undertaken, it must be concluded that the land application of wastewaters offers a viable alternative to advanced treatment processes and deserves serious consideration by many communities and industries throughout the United States. Land needs, when taken in perspective with total land uses, are not unreasonable and may, in fact, play a desirable social role by providing green belts and open areas, and preserving rich farm lands and cloistered areas. The conclusions of the report point to the almost unqualified success of this method of application, both in this country and throughout the world, when the facility has been properly operated and efforts have been made to apply sound engineering, geological and farming expertise to design, construction and control procedures.

We hope that this report will be helpful to those who must evaluate, design, and operate land application facilities.

Samuel S. Baxter, Chairman
APWA Research Foundation

SECTION I
CONCLUSIONS, RECOMMENDATIONS AND REPORT SUMMARY

CONCLUSIONS

The following conclusions are based upon the field investigations of 67 municipal and 20 industrial facilities which yielded usable data as well as information from more than 300 questionnaires, a bibliographic review, and numerous foreign contacts.

NOTE: At the time the report was prepared USEPA had not adopted a definition of *secondary treatment.* Thus, the term is used throughout the report to connote treatment beyond that normally given by primary treatment and not that defined by present regulations.

1. **Land application of wastewaters from community and industrial processing sources is practiced successfully and extensively in the United States and in many countries throughout the world.** Facilities investigated handled from less than 0.5 mgd, providing service for sixty days per year, to more than 570 mgd applied on a year-around basis.

2. **Various degrees of municipal sewage pretreatment are practiced prior to land application.** The degree of pretreatment is dependent upon the types of vegetation to be irrigated, method and rate of application, the probability of odors or ponding at the application site, and other ecological impacts and public health concerns.

3. **Under proper conditions, land application of wastewater is a workable alternative to advanced or tertiary treatment of municipal wastes.** Successful operations now in use generally rely upon conventional treatment processes to pretreat sanitary wastes equivalent to secondary treatment. Prior to application to land areas, industrial wastewaters, on the other hand, often receive no conventional treatment, other than screening.

4. **Land application of wastewaters is practiced for several specific reasons.** Among the major reasons are: to provide for supplemental irrigation water; the desirability of augmenting groundwater sources; excessive distances to suitable bodies of receiving waters or extraordinary cost to construct facilities to reach suitable disposal sites; economic feasibility, as contrasted with the cost of construction and operation of advanced or tertiary treatment facilities; and inability of conventional treatment facilities to handle difficult-to-treat wastes.

5. **Land application of wastewaters can be considered as a part of a water reuse cycle.** Emphasis should be placed on wastewater utilization, reuse and renovation – the so-called "4-R cycle." Land application in water-short areas may be considered as part of this reuse cycle. Land application is not land *disposal* inasmuch as wastes are not placed inertly and left on land areas; rather, they become a part of a dynamic system of utilization and conversion of the liquid and the nutrient components contained therein. (This requires caution in application of non-amenable wastewaters which cannot become a part of this recycle-reuse process.)

6. **Present land application facilities generally are not "stressing" the system.** Many facilities were found to be using effluent on a crop-need basis. Even where efforts were being made to use land as the only point of disposal, application rates were generally conservative and the soil-plant components of the system were not stressed to limits of assimilation or used to their optimum capacities, thus providing a large factor of safety.

7. **Small communities and food processing industries will probably continue to be the principal users of land treatment of effluents for the near future.** The ability to assemble the necessary land at proper prices and without adverse effect on local land-use practices, tend to favor the use of land application systems for such smaller installations. However, stringent requirements on discharge of effluents to receiving waters, energy shortages, or a number of other conceivable economic-environmental factors could make land application feasible and workable for larger communities or other wastewater sources.

8. **A variety of beneficial uses are being made of wastewater effluents.** Uses include irrigation of parks, golf courses, cemeteries, college grounds, street trees, highway median strips, sports grounds, ornamental fountains and artificial lakes. Wastewater effluents are also used to irrigate many types of crops, including grasses, alfalfa, corn, sorghum, citrus trees, grapes, and cotton. Forest lands also are being irrigated in many areas. Groundwater augmentation to prevent salt water intrusion is being practiced. In Mexico, a wide variety of truck garden crops has long been irrigated with effluent. Crops appeared to benefit from both the nutrients and the increased amount of water which is applied.

9. **A large variety of potential opportunities for land application of wastewater exist in many communities.** Wastewaters that are given a high degree of treatment could well be considered for irrigating large public and private facilities to relieve the demand for irrigation with potable water supplies. Golf courses, cemeteries, parkways, school grounds, parks, airports, planned unit developments, green belts, forest preserves, and marginal land and land within flood plains all offer opportunities for the useful applications of effluent to the land.

10. **Sale of effluent for beneficial use has been generally unsuccessful.** Few examples were found where a public agency had been able to obtain more than a token payment for supplying treated effluent. In several cases it was reported that land for the treatment plant had been given in consideration of a right to all or a portion of the effluent. Where an agency received a tangible dollar return, it was generally based upon use of both land and the effluent.

11. **Successful operation of a land application system requires the inputs from a variety of disciplines.** For many systems, the services of a geologist and environmental engineer are required. For systems designed to augment the indigenous crop water requirements by supplemental irrigation, the advice and guidance of an agronomist and soils specialist will be needed. For larger systems, social and behavioral scientists, as well as medical-health personnel may be required to assist in evaluating and securing acceptance of this alternative means of disposal.

12. **Operation of land application facilities can be accomplished without creating a nuisance or downgrading the adjacent environment.** The survey indicated that a majority of the facilities were conducted by well-trained personnel, aware of the need for careful operation of the systems. Training, supervision, and adequate monitoring of pertinent factors are necessary to ensure that systems will not be overstressed. If ponding on the land is not allowed, odors will not be a problem. The hazard of creating other adverse effects on the environment by discharging treated effluent on land is minimal.

13. **Environmental analysis of the effects of land application facilities reflects a general improvement of the environment rather than impairment of the indigenous ecology.** Many facilities were observed where the effluent provided the only irrigation water available. Land values for sites with a right to such wastewaters were greater than that of adjacent land because crop and forest growth was enhanced, and use of potable water supplies reduced. Farming and recreation potentials exist, as well as improved habitat for wild life.

Treatment of wastewater prior to land application has generally been dictated by the desire to use the best practical means consistent with available technology and to minimize any adverse effects upon the environment. Land application of wastewater by eliminating direct discharges of effluent into receiving waters could be regarded as satisfying the ultimate national policy goal of "zero discharge" of pollutants.

No instances of health hazards were reported from any existing facilities, although the State of Delaware indicated concern over possible virus transmission.

14. **Local public opinion – objection to becoming the recipients of "somebody else's waste" – could be a major limiting factor in the development of large land application systems at distances from wastewater sources.** Psychological concern over distasteful characteristics of effluents can result in distrust of the ability of public agencies to operate, control and manage such systems.

However, several successful examples of effective operations, such as West Herdfordshire, England, and many of the facilities surveyed and described in detail in this report, demonstrate that public acceptance can be achieved.

15. **Monitoring of land application facilities and effects has been minimal and mostly inadequate.** Few states have taken an active role in requiring use of monitoring facilities, apparently because there was no direct discharge of effluents to receiving waters. Many of the municipal systems surveyed provided little or no monitoring, inasmuch as the effluent was being used only for supplemental irrigation. Industrial systems were generally better monitored, but control, in most cases, cannot be characterized as being adequate.

16. **Energy requirements for land application systems may be an important consideration.** Reported energy requirements for most advanced and tertiary treatment proposals are very high as compared to conventional treatment. Depending upon the location and availability of land, energy requirements associated with land application techniques may be substantially less than other means of treatment and effluent management. This factor deserves further evaluation.

17. **The nature and quantity of receiving waters must be carefully evaluated prior to diverting effluent to land application.** Few existing systems were found that used underdrains to collect the renovated effluent. Rather, the groundwater aquifers received the flow. If a land application area is adjacent to the receiving water, much of the groundwater may serve to augment the flow into the receiving waters by a gradual seepage into the drainage basin. Elimination of direct wastewater discharges to a stream could unbalance the flow regimen associated with downstream beneficial uses, inhibit desirable dilution of waste discharges, interfere with the tempering of thermal water discharges, and permit the intrusion of saline waters into normally fresh water zones. The impact of effluent diversion into land areas with respect to the basic principle of riparian water rights must be considered where irrigation is planned as an alternate to discharge into surface waters in some areas.

18. **When wastewater is discharged to land and this method is used as a means of advanced treatment by natural means, the land must receive priority for this use over other optional land uses.** The needs of crop production, recreation and other benefits can be in conflict with the utilization of a land application system for the treatment of wastewater. For instance, the planting, cultivation and harvesting of crops and the use of recreation facilities may interfere with continuous applicaiton of wastewater onto land areas. The need for the system to either utilize all of the flow or provide sufficient retention storage for needed periods of non-operation must be considered. The objective of providing adequate treatment of the effluent cannot be sacrificed for other needs and uses of the land; proper handling of the wastewater must be the first priority.

19. **Choice of ground cover can play an important role in the success of a land application system.** On other than sandy soils, it appears that forested or minimally wooded or cultivated areas will accept greater rates of applicaiton of effluent without ponding than will cultivated agricultural areas. Many existing facilities utilize forest areas and grassed areas for application. Forested areas appear particularly useful for winter applications when fixed spray systems are used. In most areas Reed Canary grass is well suited for producing mulched ground cover which can enhance soil assimilation and absorption characteristics.

20. **Land application facilities that have been used for many years are available for the study of long-term effects of such use.** They offer the opportunity to study effects on soils and groundwaters. Demonstration projects should be undertaken to evaluate the effects and characteristics of climate and soil conditions on the practice of discharging effluent on land. A project should also be initiated on the methods of application of wastewater to land. However, it appears unnecessary to support separate demonstration facilities in each of several states and regions. During the course of the study several small-scale research and

demonstration projects involving land application were reviewed. Some of these projects appeared to have been instituted simply for the purpose of convincing local and state officials of the safety of this alternative method of treatment and disposal.

Specific evaluation of established systems in the various climatic zones would appear to be more fruitful than new research installations for determining long-term effects upon soil, vegetation, groundwater, and the indigenous ecology, or on the health of site workers and adjacent residents.

21. **Observations in the field and surveys of land application systems did not reveal the existence of specific health hazards and disclosed very little concern over threats to the health of on-site workers, residents of neighboring areas, domestic animals or wildlife, or of those who consume or come in contact with land-applied wastewaters.** Mail surveys of other representative municipal and industrial land application systems similarly provided no evidence of any health problems associated with this method of disposal.

Some concern over potential health hazards was, however, expressed or inferred by officials of some state agencies who supplied information about their policies on land application of effluents as an alternative means of wastewater management. Whether this concern was based on specific information or mere suspicions, founded or unfounded, could not be determined from the responses.

Inquiries have been made with inconclusive results about the health implications of land application systems by several Federal, state and local agencies, and by other quasi-governmental and public service organizations. Concern over "the unknown" was expressed for such factors as potential viral and pathogenic hazards resulting from dissemination of aerosol sprays or mists and contacts with sanitary and industrial sludge residues.

While the current studies did not disclose cause for such concerns, the bibliographic abstracts prepared as an integral part of this investigative project do include references describing possible health hazards which warrant further study and these potential problem areas should certainly not be ignored.

RECOMMENDATIONS

1. **Suggested criteria for land applications of wastewaters should be prepared by the U.S. Environmental Protection Agency to provide the basis for full consideration of the wide choices of available methods and procedures.** Criteria should be prepared in a manner which will not restrict unduly the ability of local officials to make full use of this alternative method of treating and managing wastewater.

2. **Land application must not be considered as a panacea or universal method of treatment.** Suitability of each land application system can only be determined as a result of an interdisciplinary study for the particular site. Soils, climate, degree of pretreatment, groundwater conditions and availability of suitable acreages of land are important considerations.

3. **Preparation of a suitable publication to inform the public about the practice of discharging effluent on land should be sponsored by the U.S. Environmental Protection Agency.** Public relations problems are usually encountered by agencies attempting to implement any large public wastewater disposal project. Recent efforts to consider land application of effluent as an alternative in planning for regional approaches to wastewater management have highlighted the need for such a publication.

4. **Training opportunities should be provided to bring to the attention of all disciplines involved in the consideration and evaluation of a land application facility the technical information which is available.** Widespread consideration and utilization of land application cannot be made until such time as adequate information concerning the technique involved is made available. The experience gained by those who have successfully utilized this wastewater management method should be used.

5. **Criteria for the increased use of land application methods, which could result from the implementation of Section 201 of the 1972 Amendments to the Federal Water Pollution Control Act and its emphasis on**

alternative wastes management techniques and systems, should clarify the question of whether health hazards are a factor in the use of this system of treatment and disposal. Definitive findings are essential to the acceptance of land application systems, or to their adoption for municipal or industrial effluent management. Such findings should be provided with promptness and clarity, either through evaluation of existing data or any additional necessary research. Without such positive information, published criteria might either be inadequate or tend to be too restrictive. If they are too stringent, this could endanger the proper utilization of land application systems as effective and economical solutions to water pollution control problems and the rational use of wastewater for crop and groundwater enhancement and other environmental-ecological benefits.

SUMMARY

Highlights

The American Public Works Association, in 1972, conducted an on-site field survey of approximately 100 facilities in all climatic zones where community or industrial wastewaters are being applied to the land, as contrasted to the conventional method of treating such wastes and discharging them into receiving waters.

Additional data were gathered from many existing land application facilities across the country by means of a mail survey addressed to responsible officials. Another survey was carried out to ascertain the nature and extent of State health and water pollution control regulations governing the use and control of land application systems. To augment information on U.S. practices, a survey was made of experiences gained in many foreign countries. In addition, an extensive bibliography was compiled of literature on all pertinent phases of land application practices.

The facilities surveyed were relatively large, long-established operations. These were selected to obtain as much information as possible on the operating experiences of those using this system. The surveyed facilities where community wastewaters were applied on land were predominantly located in the western and southwestern portions of the U.S., while industrial facilities were generally sited in the mid-continent and northeastern sections, because this is where the majority of such installations are in service. This method of handling wastewater has been used to meet definable needs, and is technically feasible in most areas.

Land application of effluent has been employed for a variety of reasons. These most frequently mentioned were:

1. to provide supplemental irrigation water;
2. to give economical alternative solutions for treating wastes and discharging them into receiving waters, without causing degradation of rivers, lakes and coastal waters; and
3. to overcome the lack or unavailability of suitable receiving waters and eliminate excessive costs of long outfall lines to reach suitable points of disposal into large bodies of water.

Among the major means of accomplishing land application of wastewaters are:

1. irrigation of land areas by spraying, with high-pressure or low-pressure devices, using either stationary or movable types of distribution systems;
2. ridge and furrow irrigation systems;
3. use of overland flow or flooding methods; and
4. use of infiltration lagoon or evaporation ponds.

Although facilities of all types were surveyed, this report is primarily concerned with irrigation-type facilities for supplying supplemental water to crop areas, forest areas and unharvested soil cover acreages. The other types are not as widely used because the climate or soil conditions in some locations have an adverse impact on these alternate methods of applying wastewater to land.

Irrigation-type facilities were found to be used in many instances under a wide variety of climate and soil conditions, with various degrees of prior treatment of the applied wastewater and various types of ground cover utilized.

Each method of application has inherent

advantages and disadvantages which must be evaluated for their feasibility and efficacy.

Land application of wastewaters has been practiced extensively in various parts of the world for many years, since long before the turn of the century. The majority of earlier facilities applied untreated domestic wastewaters with varying degrees of control and success. Figure 1, Land Application Sites, is a photograph of four sites indicating the variety of conditions observed at installations where land application is being practiced.

As knowledge of wastewater treatment processes improved, and techniques were developed to confine, in a relatively small area, the entire process needed to produce a "treated" effluent for disposal into receiving waters, land application was relegated, in most states, to being an undesirable and unacceptable process.

New concerns about preserving the quality and reuse of the nation's water resources have resulted in a reawakening of interest in land application as a viable alternative to conventional wastewater treatment and disposal into receiving waters. Increasing volumes of sewage and industrial wastes, growing complexity of such raw wastes, and mounting needs for water to serve growing urban and industrial processing needs, have created doubts about the ability of receiving waters to assimilate effluents which do not meet high-quality standards. In addition, increasing evidence of eutrophication of non-flowing receiving waters has focused attention on the need to eliminate the presence of nutrients in wastewater effluents. Further, the presence of toxic trace elements in effluents is sometimes considered a threat to the safety of receiving waters. Thus, advanced treatment methods have been developed and utilized to avoid discharge of such objectionable components. Inasmuch as land application appears to offer comparable or superior degrees of treatment by augmenting waste treatment with the "natural" purification offered by soil contact, land application is again being considered as one of the acceptable means of achieving full treatment of wastewaters.

However, a most important factor of the current land application concept is that it must be limited to the use of treated, disinfected wastes. Generally, effluents are being conventionally treated to meet secondary treatment quality criteria. In at least three observed facilities, applied effluents have received tertiary treatment, to the point where the effluent would fully meet the generally prescribed, as well as proposed, criteria for discharge to receiving waters. Thus, land application is being used to give a degree of advanced waste treatment, including high degrees of nutrient and bacterial removal. In this context, land application can be viewed as an alternative to physical-chemical processes and other methods of ultra-treatment which are designed to achieve a "pure" effluent.

Economics of construction cost, operating costs, energy requirements, and efficiencies of performance of land application systems must be balanced with the ability to acquire the right to apply wastewater upon the required land areas. The cost of advanced waste treatment by conventional means must be weighed in the light of the cost and complexities of land application systems.

Two informative reports were published on the subject of land application in 1972. *Green Lands–Clean Streams,* a report by Temple University Center for the Study of Federalism, is a frankly written advocacy of the land application of wastewaters and sludges. *Wastewater Management by Disposal on the Land* by the U.S. Army Corps of Engineers is a thorough review of the physical, chemical and biological interactions involved in land application. The consulting engineering firm of Metcalf and Eddy has also prepared a report for the U.S. Environmental Protection Agency, concerned with engineering considerations of land application systems entitled, *Wastewater Treatment and Reuse by Land Application*. It is to be released in 1973. These three reports, together with this report on the study conducted by the APWA Research Foundation, should be considered in evaluating land application systems, because they deal with somewhat different aspects of the common problem.

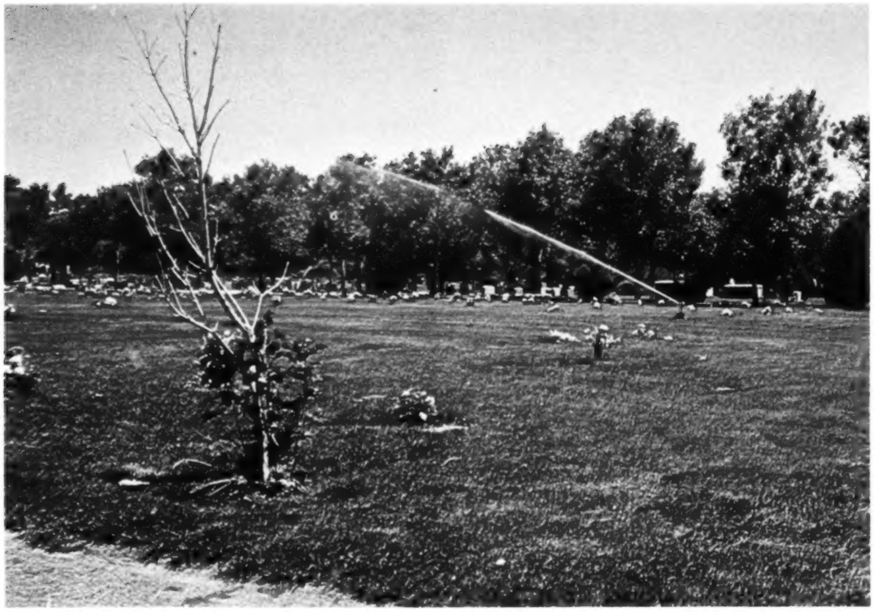
This report on the APWA studies has

made no special effort to examine the specific aspects covered in detail in the other reports. Rather, it is concerned with reporting upon the policies, practices and performances of a representative group of the relatively larger systems within the U.S.; policies, or lack of policies, of State regulatory agencies; and the experience with land application in some foreign installations.

Systems which were under construction, such as Muskegon County, Michigan, and several major domestic and industrial systems which were intimately known to Metcalf and Eddy project personnel were not investigated for this report. However, the firm of Metcalf and Eddy has supplied copies of its field interviews at such sites to APWA evaluators and data on many of these installations have been incorporated in this report. Conversely, all field information obtained during the APWA investigations was supplied directly to the firm of Metcalf and Eddy for its use in analyzing its own study results.

The following highlights from the field surveys are presented to give a composite picture of the observations made during the land application site visits:

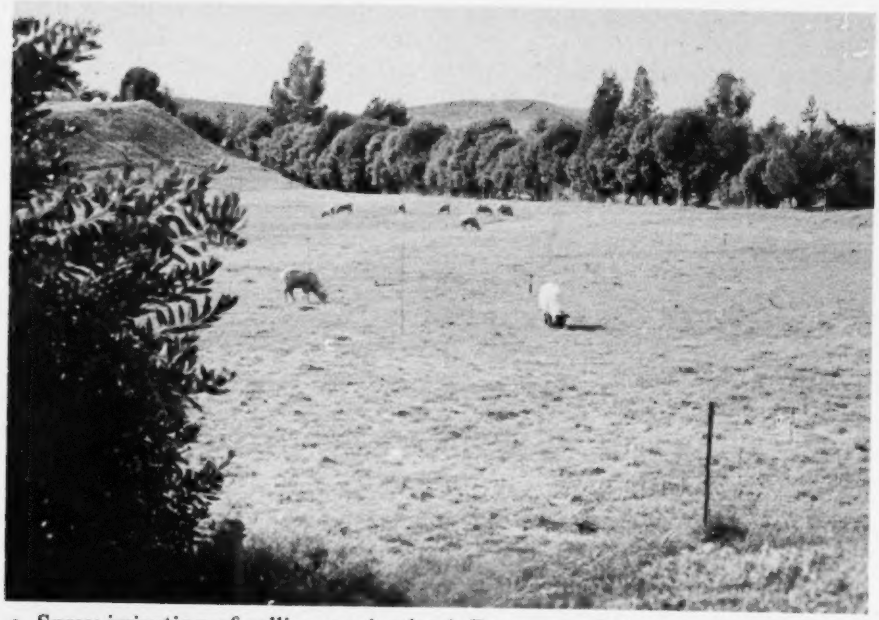
1. Communities generally use their land application system on a continuous basis. Food processing plants, the predominant industrial users of the system, generally use discharge-to-land systems for three to eight months per year.
2. Ground cover utilized for municipal systems is divided between grass and crops. Industries generally use grass cover.
3. Land application systems are generally used on a daily basis, seven days per week.
4. Application rates for crop irrigation are very low in terms of inches of water per week. Two inches or less was commonly used. (Two inches per week equals 54,300 gallons per acre per week.)
5. Many types of soils were used, although sand, loam and silt were the most common classification given. Two systems using applications over many feet of sand were applying up to eight inches per day once a week, and one system on clay was applying a daily rate of 0.1 inch.
6. Most operating agencies, municipal and industrial, are planning to either expand or continue their land application installations. The few examples of systems which had been abandoned were due to either the desire to make a higher use of the land, or because of reported overloading and poor operation of the land application facilities.
7. Industries surveyed generally treat their total waste flow by land application. Practices of municipalities varied from less than 25 percent (8), to all (34) of the wastewaters discharged.
8. Secondary treatment is generally provided by municipalities prior to land application, often times accompanied by lagooning. Industries using this system frequently treat their process wastes by screening only.
9. Spray irrigation is the most frequently used (57 facilities) method of application, although most municipalities use more than one method. Ridge and furrow irrigation is used at 23 facilities and flooding irrigation by 34 systems. Industry generally used spray irrigation.
10. Land use zoning for land application sites is predominantly classified as farming, with some residential zoning in contiguous areas.
11. Wastewater generally is transported to the application site by pressure lines, although a number of municipalities are able to utilize ditches or gravity flow pipe lines.
12. Many community land application facilities have been in use for several years – more than half for more than 15 years. Industrial systems have generally been in use for a lesser period of time.
13. Renovated wastewater is seldom collected by underdrains; rather, evaporation, plant transpiration, and groundwater recharge take up the flow.
14. Land application facilities generally do not make appreciable efforts to preclude public access to sites. Residences are frequently located adjacent to land application sites. No special effort is made to seclude land application areas from recre-



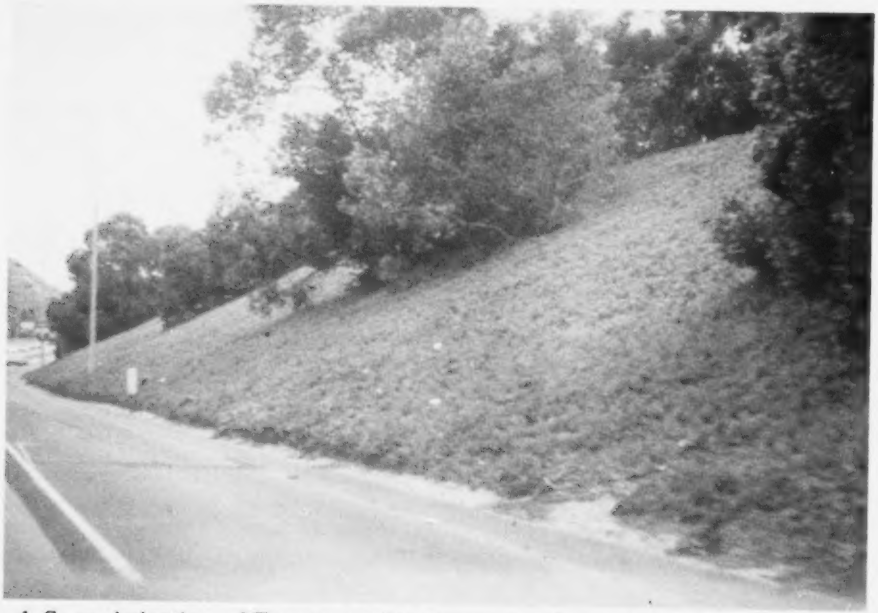
a. Spray irrigation of cemetery, Colorado Springs, Colo.

b. Spray irrigation of forest, Tallahassee, Fla.

FIGURE 1
LAND APPLICATION SITES



c. Spray irrigation of rolling grazing land, Rossmoor, Cal.



d. Spray irrigation of Freeway right-of-way, San Bernardino, Cal.

FIGURE 1
LAND APPLICATION SITES

ational facilities and from those who use these leisure sites.

15. Monitoring of groundwater quality, soil uptake of contaminants, crop uptake of wastewater components, and surface water impacts is not carried out with any consistency.

Figure 2, Application Techniques, portrays various types of spray irrigation equipment used at surveyed sites. Figure 3, Crops Irrigated with Wastewater, shows the variety of crops irrigated.

OVERVIEW OF THE REPORT

The purpose of the report is to present the details and data relating to the conduct of the study and information on possible factors influencing the handling of wastewaters from many sources, at many sites, using many diverse methods of application. This has resulted in the development of a rather large document. It answers many questions raised by the U.S. Environmental Protection Agency and other branches of government, and by municipal and industrial officials and their consultants.

This overview of the report has been prepared to provide a brief summary of the study and investigation and a concise evaluation of the principles, practices and performances of the land application systems as used in the United States and in foreign countries. Summaries of the information contained in each section of the report are presented, as well as a demographic review and a discussion of the fate of the materials applied to the land.

Section I, Conclusions, Recommendations and Summary

The sixteen conclusions drawn from the study verify the relative success of present land application systems for supplementing groundwater sources; providing economical means of effluent disposal where discharge to surface water sources would be extremely difficult and costly; improving effluent quality by soil uptake of constituents which would adversely affect receiving waters; enhancing crop growths and silviculture; and augmenting indigenous water supplies for recreational and aesthetic purposes.

Successful application of wastewaters to land areas is not without its problems. This effluent management method is not a universal panacea.

The need for programs to develop enlightened public acceptance of land application methods is strongly advocated. Over and above the problem of neutralizing the aesthetic and psychological objections to any direct or indirect contacts with wastewaters or wastes residues, fears of virological or pathological infections must also be overcome.

This public relations problem emphasizes the importance of the recommendation that studies be conducted to develop irrefutable findings on the presence or absence of health hazards in land application practices. Such findings and whatever safeguards that may be warranted must be determined before guidelines for this method of wastewater effluent management are promulgated. Guidelines are usually interpreted as "the law" rather than suggested criteria. This gives credence to the suggestion that formalization of "guidelines" be deferred until after experience is gained with the use of "interim procedures." The publication and use of such procedures and results of the studies suggested above will provide scientific information upon which to base "guidelines" for increased utilization of this treatment-disposal procedure in the future.

PRECIS OF SECTIONS OF THE REPORT

Section II, The Study

The study conducted by the APWA Research Foundation on behalf of the U.S. Environmental Protection Agency was planned to produce fundamental information needed to facilitate compliance with the intent of Section 201 of the 1972 Amendments to the Water Pollution Contract Act. The study was specifically designed to:

- Obtain design and operational data for a large number of U.S. installations in various climatic regions, which are handling wastewaters of various types and volumes; by various methods of application; for different purposes; on various types of soil, ground cover and cropping; under different local environmental conditions.

- Collect and interpret similar data on foreign installations where land application has been in effect for longer periods and under different conditions.
- Collate bibliographic records and references on all facets of land application, including design, operation, physical, chemical, pathological, virological, parasitic, aesthetic, hydrologic, agricultural, herbicultural, silvicultural benefits and detriments, and other related matters.
- Evaluate all data in terms of practical interpretation of their meaning, and as a means of producing and catalyzing the development of meaningful answers and guidelines to land application practices.

The studies, in great measure, achieved these goals.

Section III, Survey Investigations

On-site, in-depth investigations of more than 67 community and 20 industrial land application systems were carried out by trained engineering specialists. The 87 installations designated provided data of significance. These sites were chosen to be representative of national experiences with different types of wastewaters, applied to varying types of soils, ground cover and other indigenous conditions under diverse climatic conditions.

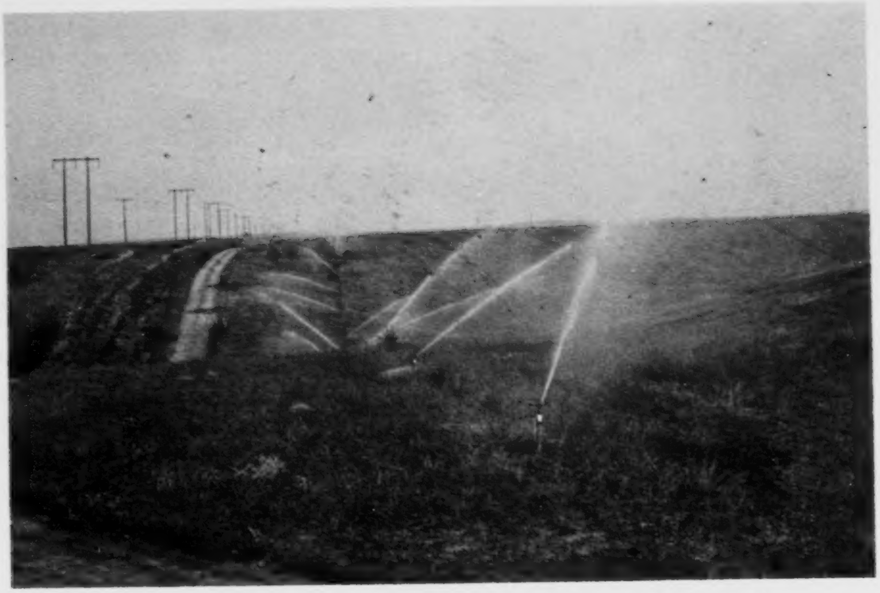
To augment the findings of the on-site surveys, a mail investigation of similar land application sites was carried out, covering the same study subjects explored by the field study team. Significant data were obtained for approximately the same number of municipal and industrial installations covered by the field studies. Five climatic zones, each with its own temperature, precipitation, humidity and seasonal characteristics, were designated and evaluation of survey findings were interpreted on the basis of the impact of climatic conditions on wastewater application to land areas and other factors influenced by meteorological phenomena.

The demographic, geographic, geologic, hydrologic and other factors and impacts of land application practices, procedures and performance are discussed later in this section.

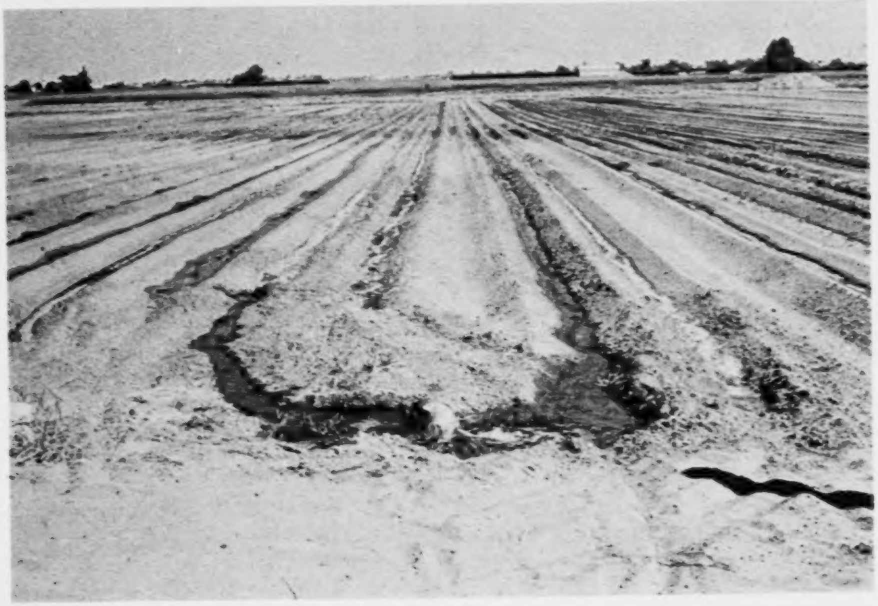
The findings of the surveys offer evidence of acceptable operating experiences, which should be useful in guiding future land application decisions. An important finding, in all of the diverse conclusions that can be drawn from field and mail survey data, is the fact that 90 percent of communities and 95 percent of industries making use of land application methods plan to continue their use; nearly 50 percent of the communities and one-fifth of the industries contemplate increasing or expanding their systems. If the "proof of the pudding" is in the performance, the approval of users is a good test of the acceptability of land application methods.

The study indicated that existing land application systems are being used predominantly, in relatively small communities and at industrial sites. Future applications may involve larger loadings and greater irrigation areas. It is significant that the costs involved in existing land application systems apparently lie within the capabilities of smaller communities and industry installations. Choice of this means of wastewater disposal has been based on various factors: Need for supplemental irrigation water; augmentation of groundwater resources; simplicity and economy of providing required degrees of treatment; problems of excessive cost of providing treatment and outfall lines to distant points of effluent discharge into suitable surface water sources; and merely "to get rid of the wastewater" in a convenient, trouble-free manner.

The following points are borne out by the report: Existing practice stresses land application of treated effluents, not raw wastewaters; the percentage of land application acreage frequently represents only a portion of the land reserved by the owners for their systems; application periods may vary from one month to twelve months a year, and from one to seven days a week, depending on climatic conditions, need for land application for excess flows, seasonal industrial processing, such as in the food industry, and other local factors; land values are relatively low, zoned for either agriculture or residential uses, often in undeveloped

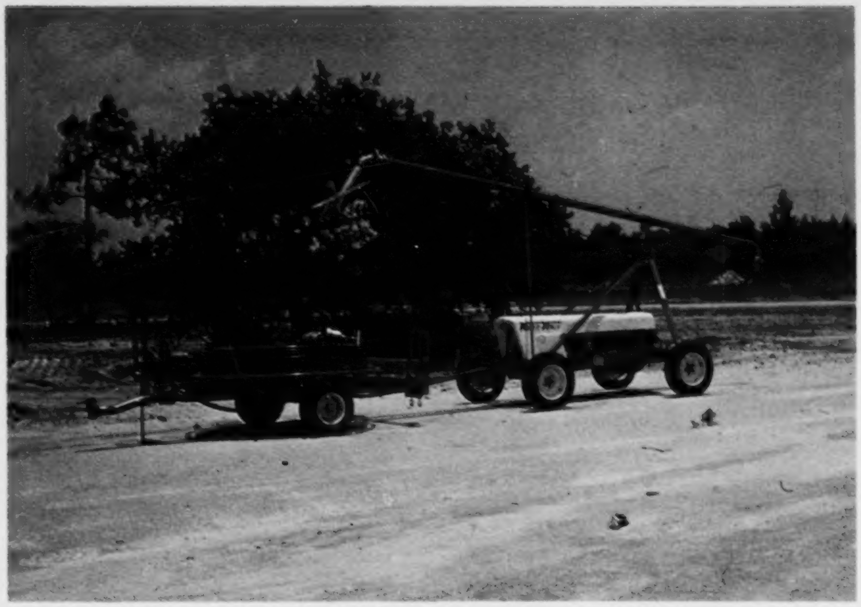


a. Remotely controlled sprinkler line on hayfield, Walla Walla, Wash.

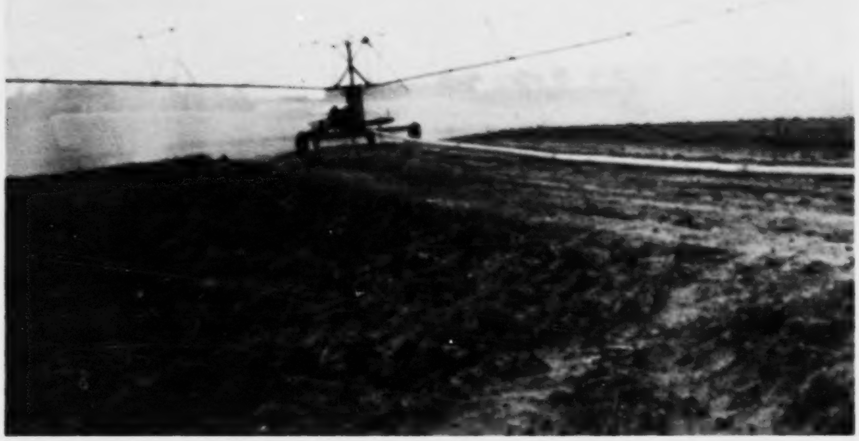


b. Ridge and furrow irrigation, Dinuba, Cal.

FIGURE 2
APPLICATION TECHNIQUES

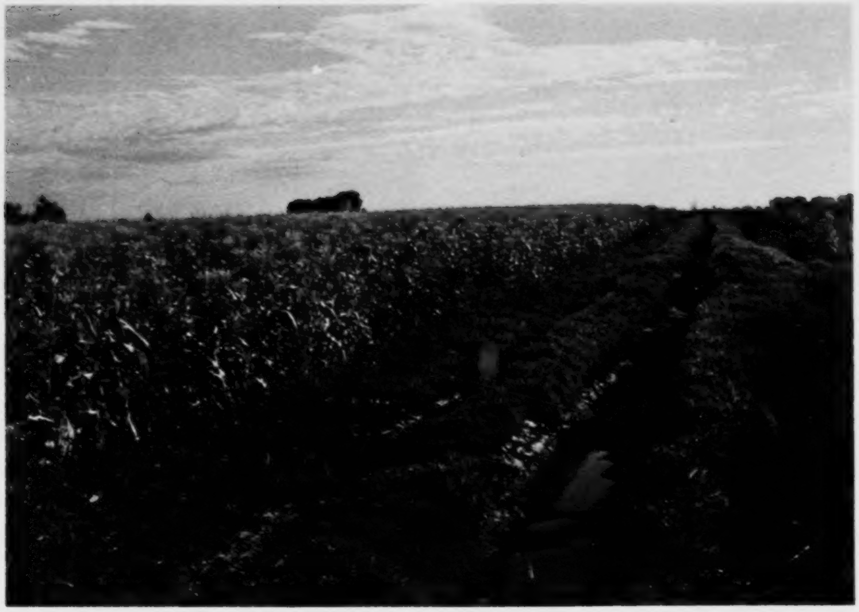


c. High pressure spray gun, Walt Disney World, Fla., for use on sand

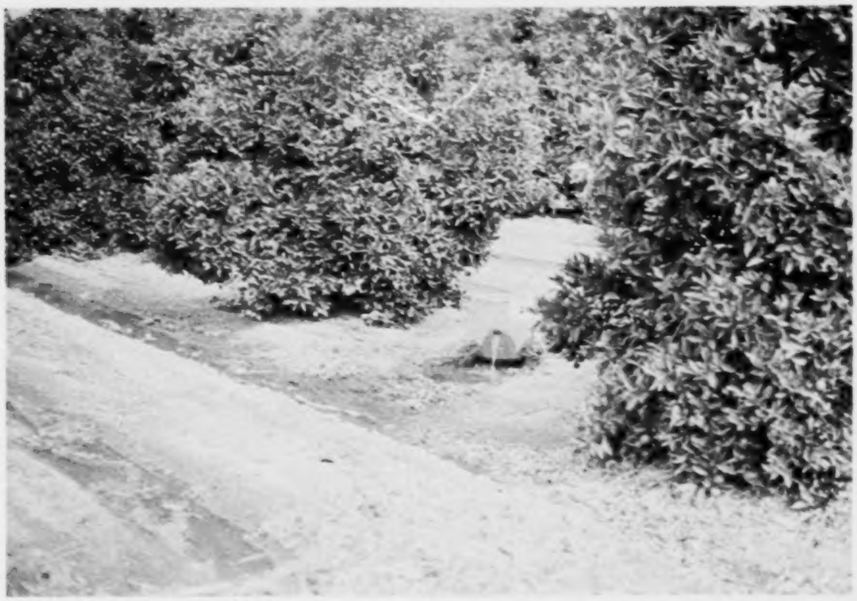


d. Spray atomizer for use on clay soil, Fairmont, Minn.

FIGURE 2
APPLICATION TECHNIQUES

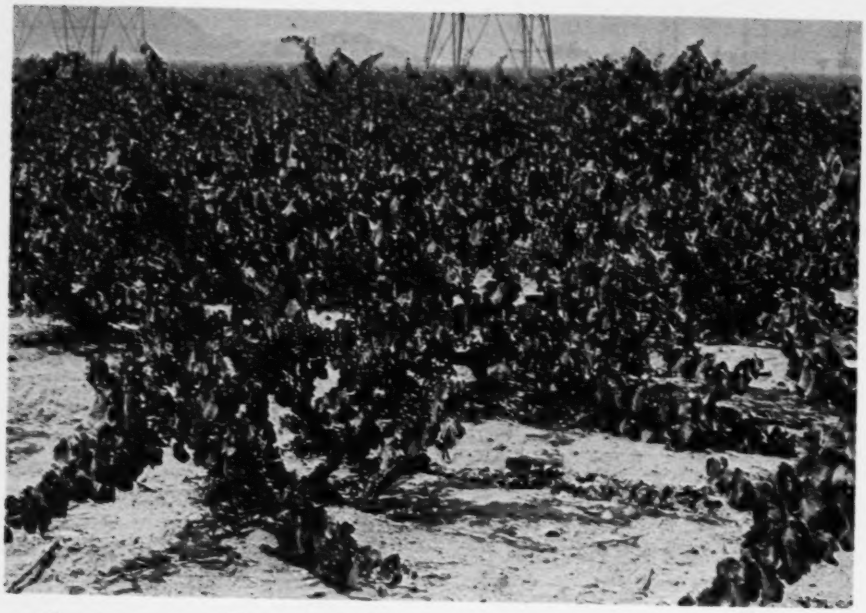


a. Corn grown at Buhl, Ida., by Green Giant Corp.

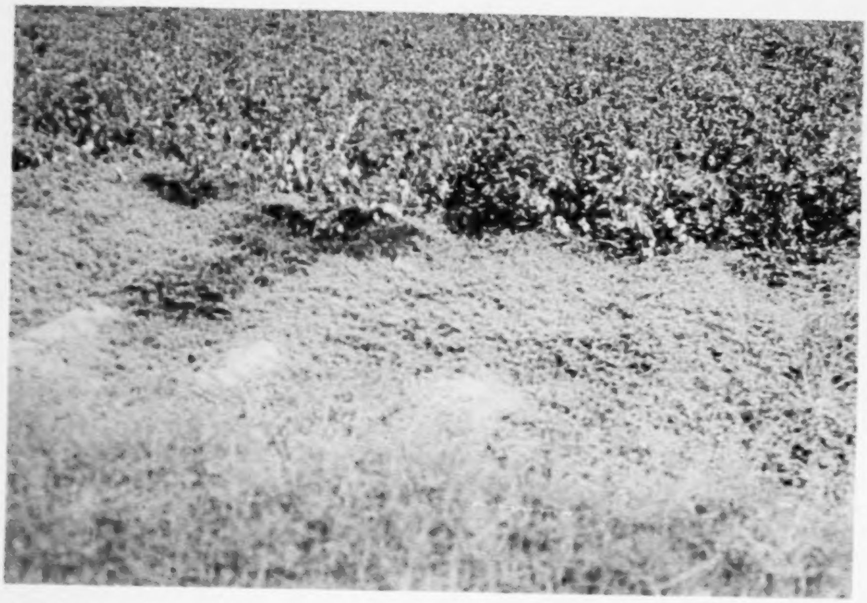


b. Citrus trees irrigated at Irvine, Calif.

FIGURE 3
CROPS IRRIGATED WITH WASTEWATER



c. Grapes grown at Fontana, Calif.



d. Cotton grown at Casa Grande, Ariz.

FIGURE 3
CROPS IRRIGATED WITH WASTEWATER

areas, and subject to minimal or no degradation of value due to use for irrigation purposes; all types of soil are utilized, with sand, clay and silt most favored; groundwater interference problems influence choice of sites, and when appropriate sites are selected, cause minimal difficulties with land application methods; predominant wastewater distribution methods are spray irrigation, overland irrigation and ridge-and-furrow irrigation.

Use of the irrigated land varies with the owners' needs and dictates, from no ground cover, to grass cover, cultivated crops, forested areas; grass is the most common ground cover in community systems. It is evident that the cropping value of supplemental irrigation with wastewaters and their nutrient components is not universally utilized.

Rates of application of wastewater effluents to the land, and duration of uninterrupted application vary from 0.1 inch per day to more than one inch per day, with varying periods of irrigation and resting. The most commonly used application rate is two inches per week. Few systems are over-stressed by such loadings; it is apparent that increased rates of application could be practiced without jeopardy to the system or the environment, and with more effective and economical utilization of assigned acreages. The follow-the-leader trend in application rates is apparent; proposed guidelines – either tentative or final – should allow establishment of rational application rates, based on the ability of the system.

Relatively little need was found for providing special environmental protection measures in land application areas. Rather, such facilities were often considered to enhance the environment. Security provisions are not universally used to protect against intrusion of outsiders. Fencing and patrolling are not universally practiced. Buffer zones to isolate land application areas and impede dispersal of aerosol sprays are used but no common practice is in effect. Monitoring of groundwater, surface water sources, soils, crops, animals and insects is practiced in some locations and minimally used in others, often dependent solely on the requirements of health authorities.

Section IV, Opinions and Regulations of State Health and Water Pollution Control Agencies

The surveys conducted by APWA with State health and water pollution control agencies indicated that most State agencies have no set policies on this phase of wastewater handling or attendant environmental impacts; do not impose specific conditions on installations; seldom inspect existing systems; or require monitoring procedures and the filing of official reports on such operations. State regulations as a minimum should require more complete supervision of land application sites, supported by definitive proof of the capabilities of such systems to serve as wastes handling facilities worthy of the term "alternative" techniques for the life of the project.

Only four States reported rules governing the types of crops that can be grown on sewage-irrigated lands. The few agencies which invoke restrictions of this nature specify the quality of effluents which may be applied to land areas. Of 27 State control agencies which participated in the data-gathering program, only 25 percent involved themselves with one or more of the 11 guideline criteria covered by the opinion survey.

In defense of this meager record of surveillance of the land application of wastewater practices, it must be said that some States have few such installations and even fewer of any major significance. In addition, States contend that they have been deeply involved with the control and regulation of conventional sewage treatment facilities and stream quality protection. Shortage of qualified personnel has been defined as the primary reason for the lack of attention to the installation, operation and monitoring of of land application systems.

In the absence of formal State

regulations, some agencies have used unofficial staff opinions as the basis of land application decisions. Similarly, each-case-for-itself decisions on health hazards have been invoked or expressed by State health agencies but a minimum of translation of such policies into specific regulatory actions was disclosed by the survey.

Section V, Summary of Foreign Experiences

Data from many countries, including Argentina, Israel, India, Hungary, Belgium, Australia and Mexico confirm the use and value of land application methods for various purposes, for a variety of growing crops, under diversified conditions, and with different results. Enhancement of soil productivity, through the mechanics of supplemental irrigation with wastewater and the enrichment of soil with the organic constituents of sewage and industrial processing waters are widely acknowledged.

Health hazards have been studied in various countries and protective measures have been invoked. Some countries, such as water-short Israel, utilize wastewaters for irrigation purposes. More than 100 systems are in service, but they tend to avoid the use of raw, untreated sewage on land growing crops that are eaten raw by humans or domesticated animals.

On this continent, the most dramatic land application system on record is located in Tula Hidalgo, Mexico, where land owned by the Federal Department of Agriculture is assigned to Ejidos – heads of families – in units of limited hectares. On 47,000 hectares (116,000 acres), 1,476,749 metric tons (1,628,115 tons) of food products are grown annually. The wastewaters from Mexico City reach the irrigation lands by canal, with 95 percent of all canal flow assigned to land application.

Section VI, Suggestions for Implementation of Land Application Systems

The surveys carried out in connection with the current study were intended to provide, and did result in, many suggestions that could be translated into "does" and "don'ts" in land application procedures. In addition, the literature searches brought added criteria to light – and served to confirm those basic facts evolved from the surveys. From these information sources, and others, the report presents "suggested procedures for the implementation of land application systems."

For the guidance of decision-makers, designers, owners and regulators of future land application installations, the report presents procedures which take into account climatic conditions and applicability of the process to specific meteorological phenomena; availability and location of land areas suitable for wastewater application; rates of application; types of soils, crops and ground cover; methods of application and their relationship with geological, topographical and hydrological conditions; types of wastewater pretreatment to assure proper and safe land application; capital and operating costs; monitoring and health protective measures; and other related aspects of system planning and implementation.

References have been drawn from many sources to support the tentative parametric procedures outlined in the report. The listed criteria are not posed as "standards," but, rather, are offered as a necessary input to the overall fund of information upon which official guidelines must be based.

Section VII, Placing Land Application of Effluents in Perspective: An Interpretation

This section of the report on the APWA studies stresses the importance of placing land application techniques in their proper perspective, and interpreting the alternative "pluses" and "minuses" on the basis of local needs and factors. It is evident that an "alternative" must be compared with something which it is to replace. Thus, determination of choice of a wastewater disposal process must be based on a full-dimensional decision; and that decision must stem from placing the land application process in proper perspective with itself and with other means of managing wastewaters.

When viewed in this light, land application technology is not a panacea for all wastes, in all areas, under all circumstances. It is not a "quick and easy" means of getting rid of unwanted wastewaters. It requires adequate pretreatment, effective operational procedures, rigid monitoring controls and rational cost evaluations. As a substitute for the return of water into the drainage basins from whence it originally came, it can affect the "cycle of water" and create an imbalance in the water resources of a region. Land application can no longer be compared with disposal of wastes by dilution. Just as conventional wastewater treatment now involves high degrees of treatment, so land application must assure that the soil will receive highly treated effluent water or that the soil will provide the equivalent of tertiary treatment and removal of deleterious components by biological-chemical-physical phenomena. The effectiveness of land application must be judged by what it accomplishes – not merely as a means of eliminating the direct discharge of comparably well-treated effluents into receiving waters.

To fulfill its full possibilities and benefits, land application must be examined from the standpoint of what has become known as the "4-R cycle" – *return* of wastewater to the local land rather than being lost by stream flowage to downstream areas; *renovation* of the wastewater by soil and vegetative actions; *recharge* of the groundwater resources which then become the reservoir aquifer which feeds surface water sources; and the *reuse* of wastewater either directly off the land or via the tapping of the groundwater reservoir. Practical examples of these land application benefits are available; they must be placed in proper perspective with the needs and potentialities of the area in which a proposed land application project will be constructed as an alternative to conventional wastewater treatment works.

Included in the appendices is a copy of the questionnaire, representative interview reports from surveyed land application sites, and the data obtained from both the on-site and mail surveys. In addition, copies of several documents pertinent to consideration of land application have been included for the benefit of the reader.

Climate

Climate is a major factor in the suitability of land application procedures, on the purpose and continuity of operation, and on the performance of this alternative technique. In recognition of the importance of climatic conditions, the study was based on choice of site investigations in five climatic regions of the United States and evaluations were aimed at determining the impact of the specific zonal meteorological characteristics on every phase of the study.

Broadly characterized, Zone A (mid and south Pacific coast) is an area of dry summers and mild wet winters; Zone B (the southwest) is an arid region, with hot, dry climate; Zone C (southeast-Gulf coast-Atlantic coast, and Pacific northwest) experiences hot wet summers and mild winters; Zone D (east-continent and northeast Atlantic coast) is subject to humid weather, with short winters and hot summers; Zone E (mid-continent and far northeast) is a humid area, with long winters and warm summers. A map indicating the location of the climate zones is included as Figure 4, Climatic Zones and Location of On-Site Surveyed Facilities, page 33.

While climatic conditions have the most significant impact on the land application principle, other factors have potential bearing: Size of the community and the industry; the amount of wastes flow; the population contributing sanitary wastes and the population equivalent of the industrial wastes contributed to the municipal sewer system; the availability of open land for irrigation use; the land-use zoning of the region; the cost of land; the type of crops to be grown with supplemental irrigation and the market needs and demands for such crops; the groundwater depth and quantities and their use for water supply purposes, protection against salt water intrusion into aquifers and other functions; the nature of the soil; the proximity of surface waters which can become recipients of conventionally treated effluents; and other correlated circumstances of local or indigenous nature.

It is not difficult to rationalize the effects of these climatic-demographic conditions on land application practices, and, conversely, the impacts of land application on these environmental conditions. It is difficult, however, to translate the findings of the study into these relationships. Efforts have been made to draw every possible relationship between these various factors but the findings are often too indeterminate to warrant such translations.

DEMOGRAPHIC EVALUATION OF LAND APPLICATION TECHNIQUES

The nature of wastes produced by community life and industrial processing, and the amounts of such wastewaters are affected by regional conditions and their impact on life and living processes. Automatically, then, the manner in which wastewaters are handled and disposed of is influenced by demography, or regional, environmental needs. For example, the degree of sewage and industrial treatment in the past was influenced by the water resource needs of regional areas and how regulatory bodies interpreted these needs to protect the natural environment and preserve public health and safety. Over and above the natural setting for any region, policies were, and will continue to be, affected by population densities, water needs, public desires and antipathies, and other factors. This represents demography in action.

If it were possible to relate the applicability of wastewater management on land areas to such factors as climatic conditions, population and population densities, economic-social patterns, and similar demographic parameters, these would serve as important guidelines for the choice of this alternative method of wastewater treatment and disposal vis-a-vis today's conventional treatment standards and the advanced degrees of effluent quality that will be required in the future. If such relationships could be established, based on the findings of the current studies reported in this document, or by parallel investigations now sponsored by the U.S. Environmental Protection Agency, the viability of the land application technique could be verified or clinically questioned.

The factors involved in a full demographic evaluation of land application practices appear to be too numerous, too complex and too interwoven to be capable of full clarification in any single study. Many of the factors are too intangible to be explained by basic survey data; the type of parameters used in the current research study could not include such incomprehensible implications. But the study did involve the relationships between land application and climatic conditions, and concurrent relationships involving urban populations and densities, industrial operations, local ecological conditions and other indigenous factors.

The following highlights can provide valuable guidance for decision-makers and designers of land application systems, even though they are not always affirmed and confirmed by study findings.

Climatic Conditions: The 67 community systems and 20 industrial land application sites covered by the on-site surveys, and the comparable numbers of such installations covered by the mail inquiry, were representative of the actual total projects in each of the five climatic zones. The major number of community systems surveyed was located in Zones A and B, with California sites predominating. These two zones represent dry and arid conditions which make supplemental water resources – reused water in the form of effluents – a precious commodity. No industrial sites in these zones were surveyed by on-site investigators because minimal use of land application techniques is made by local industrial installations. In lieu of such industrial irrigation projects, communities in Zones A and B accept industrial wastes into public sewers and onto publicly owned application sites in the form of population equivalent loadings.

In Zones C, D, and E, industrial sites were surveyed because the use of land application is practiced more generally in these parts of the nation. The industries involved are primarily food canning-processing factories, dairy processing plants, pulp and paper mills, and organic chemical manufacturing firms.

The differentiation between the zonal incidences of community systems and industry sites is explained, at least in part, by the needs for supplemental water and the uses for such water. Thus, climatic water-short and water-rich areas dictate the retention of sanitary wastewaters in the areas which produce them, or whether to permit them to flow away downstream into other receiving watersheds and water basins.

In regions A and B, water is in relatively short supply, due to dry summers and year-round aridity, and wastewaters are oftentimes considered by communities as a commodity for land irrigation, for groundwater augmentation, and for use for such ancillary purposes as golf course and highway median watering and the creation of recreational water facilities. Industries in these areas, however, as in other areas, are less concerned with such beneficial uses of wastewater and may not practice land application; they may use this management procedure primarily for the purpose of "getting rid" of such effluents in the cheapest and simplest manner.

This brings the matter of wastewater – or used water – economic and ecologic value and utilization into focus as a determining factor in the practice of land application. In arid regions, land application offers strong incentives. In wet, humid regions water-husbanding is not a vital motivating reason for land application installations; but such motivation can be found in the ecnomies of producing high-degree effluent by means of the "free" purification capabilities of soil. Whether planned as a water resource conservation procedure or not, the ultimate fate of wastewaters applied to land areas by spray irrigation and surface applications (such as ridge-and-furrow methods) is a means of enhancement of the local groundwater reservoir. The fact that 85 percent of the water stored in the United States is contained in subsurface aquifers adds significance to this wastewater fate.

Climatic, geographic and geologic conditions have other influences on the choice of wastewater disposal works. Inland areas that have no convenient receiving water resources may find it cheaper to apply wastewaters to the land rather than constructing long, expensive outfall lines from their treatment plants to suitable discharge points. On the other hand, the water-cycle imbalance which may occur in local waters by taking water supplies from them and not returning wastewater back to the same rivers and lakes may place a negative aspect on land application procedures. This type of water resource imbalance does not apply to coastal regions.

The relationship between hard winters and land application systems is obvious. In areas where full-year irrigation can be practiced, land application would have greater applicability than where adverse winter conditions would make irrigation inappropriate or inefficient. While land application is practiced in some ice, snow and sub-freezing conditions, optimum conditions are represented by year-round mild weather such as is experienced in Zones A, parts of B, and in C.

Similarly, the relationship between climatic conditions and holding pond capacities is equally understandable. Where seasonal cessation of land application is necessary, the principle of "not one drop of wastes into water resources" impells the construction and use of adequate holding volumes. "Adequacy" is a relative term; 31 percent of community and industrial systems use ponds with capacities of five days or less. In Zones A, B and C, 75 percent of the sites have holding capacities of less than 30 days, or less than needed for a full winter season. One installation in a cold zone provides a 50-mg pond for a daily flow loading of 0.5 mgd.

Of some significance, if not as pertinent as other seasonal conditions, is the amount of rainfall in humid areas which may impede soil absorption of applied wastewaters and require the use of flow-equalization or flow holding of excess waters until required rates of application can be reinstated. As stated, where rainfall is generally adequate, if not always predictable, land applicaton for enhancement of crop growths, forest growths and groundwater augmentation is not the dominant reason for the choice of this wastewater management technique.

While the survey studies brought these climatic relationships into focus, they did not always provide positive proof of these effects and impacts. This does not detract from the validity of the above observations. No attempt has been made to draw all possible climatic-environmental relationships with land application principles and practices, however, the rationale is adequate to demonstrate that there is a direct correlation which must be considered before choice of wastewater management is made for each individual project. No set standards can be established; each case will require its own relationship evaluation.

Size of Wastewater Facility: In the case of publicly owned systems, the population served is translatable into volumetric and qualitative loadings. For industries, the flow loading is a factor of volume and population equivalency of the organic constituents, as measured by BOD, COD, suspended solids and other significant parameters.

The surveys indicated that some outstanding large community land application installations have been in service in the United States and foreign countries. However, the major percentage of current installations are in the smaller-size range.

The on-site surveys disclosed that 73 percent of communities studied have land application capacities of under 5 mgd; the mail survey covered no community systems with over 10-mgd capacity. Industry installations covered by the on-site surveys were all under 5-mgd capacities; the mail-surveyed installations were all under 10-mgd size. It is conjectured that the small cities and industries have found land application within their economic range and that adequate conventional treatment would have been more costly.

Size factors are numerous but few showed definitive relationships with other land application site acreage parameters. The area used for irrigation application varied without basic reason from the total acreage owned by the community or industry. In some cases the major extent of the area is used for distribution; in other instances only a portion is so used, the rest of the acreage being devoted to holding ponds, buffer zone and general isolation of sites.

The size of the area varies, naturally, with the volume of flow applied, the nature of the soil and its absorptive character. The effect of climatic conditions, such as rainfall, humidity and temperature, on irrigation area purchased by communities and industries is minimal, despite any impression that such a direct relationship should exist. No specific trend was found in buffer zone regulations and usage. The open land available for such buffering or isolation facilities is undoubtedly influenced by State regulatory agency requirements, the type of distribution systems used (spray irrigation tends to be associated with buffering acres and plantings to impede the off-site dissemination of aerosol mists and particulates.)

Continuity of Operation: The relationship between continuity of wastewater application, on a days-per-week or a months-per-year basis, and land acreages used for land application was found to be indeterminate. Continuity of operation appeared to be dictated by other factors than availability of site acreage. It is obvious that rates of application should have a bearing on the land areas required, particularly on sites that are limited in size and not over-generous in dimensions. While the analysis of study data does not disclose this relationship, it is undebatable since the failure of irrigated land to handle distributed wastewaters for planned periods will necessitate the resting of such areas and the immediate utilization of other equivalent acreages to replace the overloaded or ponded soil plots.

If wastewater production is in effect for longer weekly or monthly periods and pond storage capacity is not available to retain excess flows, irrigation areas may be affected by the requirement that direct application of produced flows must be provided. Similarly, the land-need requirements for any site will be influenced by whether the system will function on a twelve-month basis of shorter yearly periods.

Communities tend to maintain yearly continuity of land application more completely than industries; broadly interpreted, communities operate full-year at 60 percent of installations, and industries at 40 percent of sites. The relationship between climate and continuity of irrigation was partially clarified by the subject study, despite the fact that positive patterns were not confirmed. The on-site survey-interview procedures used in the study disclosed that twelve-month continuity of community operation for Zones A, B, C, D and E was practiced in 76, 63, 56, 71 and 67 percent of sites, respectively, while industrial systems showed similar, year-round irrigation service in Zones C, D and E of 50, 56 and 30 percent of sites, respectively.

The mail survey showed that industries in Zones A and B (not surveyed in the on-site program) operated on a 12-month basis at 100 percent of the sites involved, with 100 percent of the Zone C community installations functioning on a full-year basis. Thus, the zonal factors showed little effect of widely divergent climatic conditions on whether systems functioned without cessation.

Full-week service seemed to be dictated more by the actual purpose of land application than by other factors. Full-week irrigation was found to be more common when crop irrigation was practiced than when wastewater disposal onto grass-cover lands was utilized for groundwater augmentation or for the simple purpose of effluent disposal. Application rates and continuity of irrigation were, surprisingly, unaffected by soil types.

Methods of Distribution: The relationship between the method of application and climatic conditions was brought into focus by the study. In general, spray irrigation is more commonly used in humid areas than in arid sectors; and surface application techniques, such as ridge-and-furrow irrigation and overland irrigation, are more frequently utilized in arid regions. Zones A and B were characterized by surface application sites.

The relationship between size of site and type of distribution used showed a trend of more or less specificity. Smaller sites were served by twice as many spray systems as surface application facilities. Larger sites, more than 1,000 acres in size, were usually equipped with surface application systems; intermediate-sized sites, from about 100 acres to 1,000 acres, utilized spray and surface application systems about equally. In surface application installations, so-called overland flooding which depends on sheet-flow action has been used more frequently than ridge-and-furrow distribution.

No specific correlation was found between distribution methods and soil types, but some generalized patterns were evaluated: Spray irrigation is more commonly used on loam, silt and clay lands; spray and surface application methods are generally used equally on more granular or sandy soils. Surface application methods were found more frequently on crop lands or on unplanted, non-cover areas. Spray irrigation was found more frequently on crop lands and forested acreages. Community sites handling under 1-mgd flows were most commonly grass-covered, while larger areas of over 1-mgd capacity generally stressed crop growth. Forest irrigation was practiced more frequently in humid areas than arid regions, probably because tree growth is more common in the former climatic regions. Cropping on arid region lands is relatively common, indicating the value of wastewater for supplemental irrigation.

Groundwater depths are a dominant factor in choice of sites but, once acquired, these application lands experience minimal impacts on choice of application methods and on operation performance. Obviously, groundwater depths are greater in arid regions and are less of a factor in choice of land application sites. Application rates, while not consistently influenced by climatic conditions or soil character, and while varying minimally from the almost traditional level of one-half inch per day and two inches per week, are influenced by aridity and high humidity-precipitation conditions.

Land Availability, Land-Use and Land Value: A direct relationship between demographic criteria and land availability, zoning use and acreage price is unavoidable. The first requirement of a land application system is *land.* It must be available in reasonably close proximity to the source of community or industrial wastes; the land must be useable for wastewater application by zoning and other use regulations; the price must not be prohibitive.

These conditions are most commonly met in areas of low population density where open lands are available, and where undeveloped and properly zoned properties can be purchased at relatively low cost. This is why the surveys showed the predominance of land systems in use by small communities and relatively small industries, and land prices ranging basically in the under-$500 per acre price level. Areas of the nation will become progressively more densely populated because over a million acres of rural lands are absorbed annually in urbanization and related facets of community growth. The availability of nearby lands, zoned for agriculture or residential purposes, and priced at low enough levels, will become a greater problem for users of land application systems. The solution may parallel the experiences involved in the proposed Chicago metropolitan area project: Deliver wastewater to distant points where sites of adequate size, proper zoning and moderately low price exist. The cost of long-distance wastewater transmission will become an important factor in determining the economic feasibility of land disposal.

The impact of land application installations on neighboring areas and their residents can be in direct ratio to population density. While existing systems have demonstrated their ability to be "good neighbors" to residents living as close as 500 feet of application sites, this close proximity may not be good practice in all cases. Reported complaints have been minimal against present installations despite the fact that, for example, 20 percent of community systems in Zone A are located less than 500 feet from the nearest neighbors and 22 percent are similarly located in Zone B. Industrial sites are located in Zones C, D and E within 500 feet of residences in 10, 10 and 21 percent of the cases investigated, respectively.

The relationship between local demographic conditions and land application system monitoring is obvious. The degree of monitoring was found to be less related to zone climatological conditions than to State health and water pollution control regulations in the limited cases where such governmental stipulations are imposed. It is understandable that increasing population intrusions in an area, and the density of the residential population, will dictate that closer attention should be given to the impacts of land application on land and water resources and on persons exposed to actual wastewater, sludge residues, spray mists and animal and insects which come in contact with irrigation liquids and vegetative growths. The frequency and location of monitoring points, such as test wells and other sampling facilities, and the extent of monitoring parameters will be intensified in the future to satisfy actual hazards or the psychological impressions of local residents.

Site security measures, such as fencing, may be required and buffer zones may be specified. Operation and maintenance costs will react to all such monitoring and security requirements but the reasonable cost levels for present systems could be increased without seriously affecting the feasibility and economy of land application techniques. Future wastewater treatment works, particularly those requiring full secondary treatment and processing to remove such components as phosphorous, nitrogen, trace metals and organic pesticides, will require similar augmentation of present scientific laboratory control and site safety and security measures.

FATE OF MATERIALS APPLIED TO THE LAND

To complete this extended summary of the land application of wastewater, a review of the fate of applied materials is presented. It rounds out the information which has been presented. Appendix I contains copies of papers entitled "Experience with Land Spreading of Municipal Effluents," and "Fate of Materials Applied." Both papers were prepared by Richard E. Thomas, Soil Scientist, and Robert S. Kerr, Water Research Center, Ada, Oklahoma.

These papers, as well as several exhibits appearing in the body of the report, have been included to provide the reader with information on this subject which is not otherwise readily available.

For determining the applicability of land-use of wastewaters, it is important to know with some measure of certainty what the fate of wastewater components will be.

The materials contained in wastewaters are reminiscent of the origin of these flows – either sanitary, sanitary and combined storm water, industrial process waters, or combinations of sanitary and industrial wastes. Since the application of raw wastewaters onto land areas is not contemplated under the definition of this alternative wastes management technique, all such wastes have been subjected to some degree of pretreatment before they are distributed onto land areas. The purpose of monitoring of effluent flows onto land areas is to ascertain the composition of the wastewater *after* the stages of pretreatment provided.

A classification of wastewater materals could be: suspended materials; major plant nutrients; and other constituents. Another deliniation of the wastewater components, based on the actual physical nature of the substances is: suspended solids; colloidal solids; dissolved organic materials; and dissolved inorganic substances.

The fate of these substances during the process of land application will vary with the type of distribution system, the nature of the soil, the rate of application, the climate, the resting periods, and the location and proximity of the groundwater aquifer and the surface water source which receives runoff from the site. The phenomena involved include: The physical condition of entrapment or mechanical filtration; the biological, biochemical, electrochemical and other manifestations in, and in contact with the soil; evaporative factors; atmospheric oxidation; bacteriological, germicidal and bacteriophage or anti-contamination reactions, and others which are not totally understood even by highly trained and experienced scientists.

Suspended solids entrapped in the interstices of the soil or adhering to soil particle by electrochemical entrainment can experience biological oxidation and decomposition into stabilized substances. The fate of this suspended material can vary; it can remain in the soil to form humus soil conditioning or nutritive material or, in very coarse media, it might be sloughed off and percolated into lower soil depths or into the groundwater.

Colloidal materials – solids of minute size which may be able to filter through soil media – can be coalesced or coagulated by electrochemical agglomeration and then adsorbed onto soil particles. The fate of this material, normally considered to possess electrical charge, may parallel that of true suspended solids, by oxidation-digestion phenomena. Accumulations in the soil may affect the rate of application of subsequent wastewater loadings.

Organic dissolved solids may be utilized by plant crops, retained in the body of the soil by chemical fixation or other bonding phenomena, or may be oxidized by atmospheric reactions, in the course of air contact with sprays or sheets of wastewater flowing over the land.

A major concern is centered on the nitrogen and phosphorous in wastewaters. The presence of these dissolved constituents can influence the use of land application systems in lieu of advanced treatment and discharge into surface receiving waters, primarily because they can act as "triggers" in the eutrophication of surface waters. If these materials can adversely "fertilize" lakes, why can they not be used to fertilize land?

The fate of nitrogen and phosphorous will be influenced by many factors, including the type of wastewater distribution system utilized, and the type of ground cover and crops grown. The factors involved in the different land application methods are covered in excellent detail in the before-referenced papers and it is not the intent here to explore these manifestations, beyond brief reference to the fact that the fate of these two basic elements can be regulated by proper practices to avoid serious effects on groundwater or surface water sources. The ability of soil to retain and hold phosphorous is more important than its capacity to handle nitrogen because phosphorous delivery to the soil may be greater than the crop uptake ability to utilize it. Fortunately, soil retention is able to prevent phosphorous intrusion into groundwaters that are sufficiently deep below the surface of land application sites.

Nitrogen could enter the groundwater in concentrations that might exceed the safe levels of this material in water for human consumption. However, the ability of land application techniques to complete a nitrification-denitrification cycle can be utilized to prevent this fate, as is used in the spray-runoff principle. A substantial proportion of the phosphorous contained in applied wastewaters in the same spray-runoff process could reach surface water sources unless steps are taken to improve phosphorous removal by land contact.

Other constituents of land-applied wastewaters have fates that may influence the use of land methods, either in favor of, or in opposition to this alternative process. These include heavy metals, even in trace amounts, pesticides and other organo-compounds, and various salts. Evapotranspiration of liquids from soil, vegetative surfaces or water surfaces will not change the fate of these dissolved materials; the evaporative process parallels the distillation phenomenon, in that the water is converted to vapor or gaseous form and the solids are thus concentrated in the soil or vegetation. Salts may thus reach the groundwater by percolation and leaching action. Heavy metals and pesticides can undergo physical, chemical and biochemical interactions with the soil, making land application an auxiliary means of providing so-called "tertiary" treatment for wastewaters, in lieu of more complex and more costly artificial wastes treatment processes.

To repeat a previous statement, the intent of this dissertation on the fate of materials applied to land areas is to point out that the soil and vegetative forms do offer a "bonus" factor that must be given consideration in determining the future of the land application process. Current concern about the impacts of nitrates, phosphorous, trace metals, pesticides and other organic compounds on receiving waters is sufficient reason for knowing more about the fate of these objectionable materials in the land application process. More remains to be known about them, and about the way various methods of wastewater distribution, various types of soil and topographic and climatic conditions, and other factors and combinations of factors, influence their fate.

The fate of wastewater contaminants during the land application process, in short, offers opportunities for beneficial use for soil and crop enhancement which must be considered as a "plus" for this alternative technique. In addition, the capability of the land application system to remove, modify and stabilize pollutants which would require augmented processing in conventional sewage treatment systems offers another advantage for this alternative management procedure. But, these benefits must be evaluated in the light of whether the applied materials will in any way adversely affect the water and soil environment of the region where land application systems will be utilized. Only through a weighing of the benefits and hazards can the feasibility and applicability of land application processes be properly judged for each specific installation and each specific wastes problem.

SECTION II
THE STUDY

The American Public Works Research Foundation has completed a national study of the purposes, practices and performances of representative installations which apply effluents of sewage treatment, industrial-commercial, or joint sewage-wastes treatment facilities to land areas. This project, sponsored by the United States Environmental Protection Agency (USEPA), revealed technical and practical information which should be of value in assessing policies of Federal, state, local and private agencies and entities in relation to so-called "alternative" methods of discharging wastewater to land areas instead of to the Nation's water resources.

The contract studies, and their conclusions and recommendations, have been planned and executed to provide the Administrator of the United States Environmental Protection Agency with information upon which the guidelines for the Federal Water Pollution Control Act Amendments of 1972 and the duties of Administrator can be based.

Section 201 (g) (2) of the Act stipulates that:

"The Administrator shall not make grants from funds authorized for any fiscal year beginning after June 30, 1974, to any State, municipality, or intermunicipal or interstate agency for the erection, building, acquisition, alteration, remodeling, improvement, or extension of treatment works unless the grant applicant has satisfactorily demonstrated to the Administrator that (A) alternative waste management techniques have been studied and evaluated and the works proposed for grant assistance will provide for the application of the best practicable waste treatment technology over the life of the works consistent with the purposes of this title."

Section 212 of the Act further emphasizes land application of effluents as a possible alternative to the so-called conventional method of discharging adequately treated wastewaters into watercourses. Section 212 defines . . .

(2) (A)--the term *treatment works* ". . . as any devices and systems used in the storage, treatment, recycling and reclamation of municipal sewage or industrial wastes of a liquid nature to implement section 201 of this Act, or necessary to recycle or reuse water at the most economical cost over the estimated life of the works . . . ."

In addition, it defines *treatment works* as

". . . any other method or system for preventing, abating, reducing, storing, treating, separating, or disposing of municipal waste."

Section 212 of the Act further stipulates that

". . . any application for construction grants which includes wholly or in part such methods or systems shall, in accordance with guidelines published by the Administrator . . . contain adequate data and analysis demonstrating such proposal to be, over the life of such works, the cost efficient alternative . . . ."

Thus, the study must also provide information on the practicality and economy of the process of land application of effluents to aid the Administrator in evaluating this process in accordance with the provisions of the Act.

Purpose of the Contract Investigation

Under the terms of the contract covering this study, the purpose was defined in the following terms:

"The Contractor shall undertake a survey of existing municipal and industrial systems for wastewater treatment and/or reuse by land application . . . to ascertain from local design and operational procedures, effectiveness of treatment, costs, benefits, problem areas, and a general evaluation."

The disposal of adequately treated wastewater effluents onto land areas is one of the presumed "alternative waste treatment management techniques" available. The surveying, inventory, verification and evaluation of this methodology in the United

States appeared desirable.

The specific task, among other goals the fact-finding investigation, covered the following four phases:

- Affirmation of existing data on land application sites and installations reported in various Federal and state surveys and records, and other data covering application of effluents of varying types, volumes and qualities onto land areas of various types and into groundwaters of differing characteristics.
- Gathering of background data on the use of land application methodologies in foreign countries, by means of the collation of technical reports and documentations and by the actual inspection of installations by APWA research personnel.
- Collation of bibliographic records and other references on the subject of land application of effluents, including the factors of design, decision, construction, operation and maintenance, environmental benefits, detrimental effects on land and water resources, impact on vegetation and silviculture growths, methods of application, cost, public health and nuisance dangers, regulatory standards and monitoring requirements and other pertinent matters.
- Evaluation of available data on the conceptual design, construction, operation and maintenance factors of land application in order to: Clarify specific factors and criteria; establish guidelines on the applicability of the process to actual soil, climate, regional, socio-economic-demographic conditions and achievable results; and assess these factors in terms of effective disposal costs, benefits and detriments to the environment, public health and other criteria.

- Suggesting of guidelines that will dictate the feasibility and desirability of using land application as an effective and economical alternative to the discharge of effluents into receiving waters.

Conducting the Fact-Finding Survey

The first phase of the study undertaken by APWA involved the validation of statistical records of existing effluent land application installations in the United States. It was obviously impossible to carry out a total verification of all of the more than 1,000 listed installations utilizing land area irrigation methods in the United States. Utilizing available records which included USEPA inventories and a report by the State Conference of Sanitary Engineers (1965), the survey chose more than 500 municipal land application systems and approximately 200 industrial-commercial facilities with handling capacities of over 200,000-gpd capacities. The municipal installations included all systems of more than 0.5-mgd capacity. Other units were selected to obtain a broad geographical representation. Data on these municipal and industrial systems were requested to verify the accuracy of reported information on their existing or abandoned facilities. The information requested covered:

- Designation of the municipal agency or company operating the system
- The beginning date of the operation
- Flow rates
- Degrees of pretreatment
- Methods of wastewater effluent application to the land disposal site
- Use of land for crops, grazing and other purposes
- Official responsible for systems operation

In addition, the American Public Works Association utilized its monthly APWA REPORTER to publish a request for information on land application practices, covering the same items contained in the verification survey questionnaire. This inquiry resulted in some additional sites being identified.

The main function of the investigations was to determine the actual on-site practices and performances of representative land application installations and to distill from these facts the type of decision, design and operation guidelines which will be needed by the Administrator of the USEPA to meet the requirements of the 1972 Amendments to the Federal Water Pollution Control Act.

The on-site, in-depth investigations of representative installations were carried out at approximately 75 municipal systems and 25 industrial-commercial systems. This work was performed by means of in-the-field investigations-interviews. Municipal systems selected for field interviews were chosen to meet the following criteria:

1. All applications with a flow rate of one mgd in states with less than five facilities. For states with more than five facilities, 25 percent of the remaining facilities may be visited.
2. Within states, broad geographical coverage will be attempted where optional choices are available.
3. The sampling obtained from (1) and (2), above, will be reviewed and if necessary to achieve a minimum of five sampling facilities in each of the following climatic classifications, facilities with flow rates between 0.5 and 1.0 mgd will be selected:
    a. hot - arid
    b. cold - arid
    c. warm - humid
    d. cold - humid

Commercial installations were chosen to represent at least one system of representative varieties of industrial users.

Section III contains analyses of the survey questionnaires prepared by the on-site investigators. Appendix A presents the questionnaire used in the on-site surveys. Appendix B contains field evaluations of the systems, and Appendix C contains a tabulation of the data gathered in the surveys. The choice of approximately 100 in-the-field investigation installations assured the authenticity of the national analytical data, in terms of representative information on the "how," "where" and "why" of effluent land application.

The field survey was augmented by a mailing of a full-scale questionnaire inquiry to 300 municipal agencies and 200 industrial-commercial firms. The questionnaire was the same as that used in the field interview work as contained in Appendix A. The questions covered:

- Community and manufacturing data
- Land applicaton facilities
- Types of wastes treated and effluent quality
- Methods of effluent application to the land and the volume applied
- Disposal site acreages, soil conditions and land-use zoning
- Groundwater quality monitoring
- Climatic conditions
- Crop production and income yield
- Costs of land and facilities construction
- Costs of operation and maintenance
- Evaluation of hazards to the land and water resources of the region

Data from the limited return from the mailed questionnaires are included in Appendix D. These survey questionnaires and the evaluation of the national findings provided the information certification required under the terms of the contract.

Statistics, however, are no more dependable than the raw information used to develop findings and interpretations. Therefore, the contract study was carried out with the ultimate goal of providing the most dependable information on land application practices. A further goal concerned evaluating the data in terms of guidelines on how, where and by what means this alternative method of effluent disposal could be utilized most effectively and economically.

The analytical evaluation of survey data covered such factors as:

- State and regional implications
- Wastewater flows
- Volumes and types of raw sewage and industrial wastes
- Volumes and types of treated wastewater effluents applied to land areas
- Land application rates
- Methods of application
- Seasonal practices and problems
- Pretreatment methods employed to make land application workable and dependable
- Ground cover conditions
- Groundwater quality impacts
- Soil uptake capabilities for wastewater constituents and contaminants

- Agriculture and silviculture utilization of nutrient and irrigation values of applied wastewaters
- Incomes from crops and other soil yields balanced against hazards of crop contamination
- Demographic-sociologic impacts of land application
- Health and nuisance hazards and protective measures
- State and regional water pollution control policies and controls relating to land application
- Other applicable criteria

The ultimate purpose of these data evaluation goals was to evolve suggested guidelines for choosing effluent application methods, establishing design standards, and determining operating and maintenance regulations to assure the safe and dependable use of this alternative method of effluent land utilization. Section VI presents guidelines on the implementation of land application systems, covering these considerations.

Two surveys were also made of state agencies to determine applicable state regulations and guidelines governing the design and operation of land irrigation systems, and rules and regulations governing the use of crops grown with wastewaters. The results are presented in Section IV.

The World Health Organization (WHO) has designated one or more organization in many countries as WHO Contributing Members. The American Public Works Association is a representative of the United States. As such, APWA requested other members to supply information concerning land application practices and regulations in their countries. Many replies were received; however, much of the material was in languages other than English.

Many documents were translated by the USEPA, and a summary of foreign practice is presented in Section V.

SECTION III
SURVEY INVESTIGATIONS

The application of wastewater effluents on the land is being practiced at several hundred sites throughout the United States. These land utilization systems employ a variety of land types and methods to dispose of various types of effluents with varying results. A careful summary and evaluation of existing practices and performance at these installations can provide information to guide future decision-making on this alternative method of treating and disposing of sewage and industrial wastes. Representative information on the design, operation and performance of major land application systems can serve as the basis for defining good practice and guiding the planning, designing, constructing and operating of future systems.

On-site engineering investigations of community and industrial land application systems were used to gain this reliable information. Supplementary information on existing systems was also obtained by use of a mail questionnnaire survey. The following data represent the results of these surveys. The presentation and evaluation of these data will differentiate between the two data sources on the basis that the most obviously reliable data were derived from on-site surveys.

Basic Survey Information

On-site investigations of 67 community and 20 industrial land disposal systems produced the basic data presented within the following sections. The additional systems surveyed did not contain enough data to warrant evaluation, or they employed percolation or evaporation ponds as part of their operation. By the same token, mail surveys of 86 community and 35 industrial land application systems form the basis of the supplementary component of the study. The mail survey, as in the case of the on-site survey, was affected by the limitations inherent in the responses received. The missing data and the inability of a questionnaire form to adequately describe the operation of each system must be considered in evaluating the results of the mail survey. Both methods of survey produced data in the following categories:

- Community and industrial wastewater source information
- Wastewater treatment and transport methods
- Land application system areas and distribution methods
- Disposal field characteristics
- Land application system operations
- Systems and environmental monitoring and performance
- Systems zoning, land values, capital investment and operating and maintenance costs
- Miscellaneous system returns

As may be expected, some omissions and gaps exist within the collected data. Some of the data categories specified may be found incomplete; these will be indicated. Any findings drawn from the accumulated data will, of course, be subject to these limitations.

The primary classification of all the systems surveyed relates to their geographical location within five climatic zones in the continental United States. Metcalf and Eddy, Engineers, developed these climatic regions in connection with their work for USEPA on a related project. The general conditions of climate which characterize each region are:

Zone A – Mediterranean Climate: dry summers and mild, wet winters.

Zone B – Arid Climate: hot and dry

Zone C – Humid Subtropical Climate: mild winters and hot, wet summers.

Zone D – Humid Continental Climate: short winters and hot summers

Zone E – Humid Continental Climate: long winters and warm summers.

Appendix G,Climate Classification, explains the rationale used to select the specific boundaries of the zones.

The boundaries of these climatic zones appear in Figure 4: Climatic Regions and

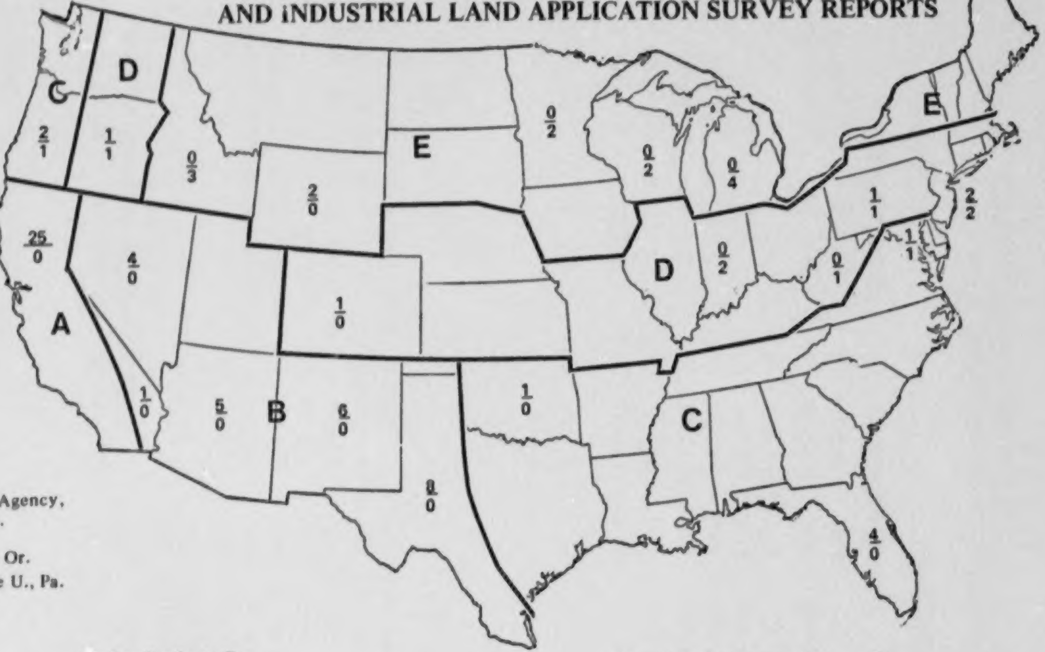
Locations of On-Site Community and Industrial Land Application Survey Reports. The number and location of the community and industrial systems surveyed on-site also appears within the insert blocks – the upper value representing the former installations and the lower values, the latter. At least one on-site community system survey was made in each state in Zones A and B; no on-site industrial system surveys, however, were conducted in these areas.

Table 1, Distribution of Communities and Industries Surveyed On-Site by State and Climatic Zone, summarizes the number of systems and population and/or population equivalent for each state. Community systems were surveyed in 17 states and industrial systems in 11 states. A summary of these data by climatic zone appears in Table 2, Distribution of Communities and Industries Surveyed On-Site by Climatic Zone. Some 72 percent (48) of the communities were located

TABLE 1
DISTRIBUTION OF COMMUNITIES AND INDUSTRIES SURVEYED ON-SITE BY STATE AND CLIMATIC ZONE

	Communities						Industries			
	Survey Reports		Population Serves				Survey Reports		Population Served	
States in Climatic Zone	Number	Percent	Population	Percent	Population Equivalent	Percent	Number	Percent	Population Equivalent	Percent
A										
California	25	37.3	1,152,300	43.1	1,907,600	46.4				
B										
Arizona	5	7.4	359,500	13.4	558,100	13.5				
California	1	1.5	22,000	0.8	35,000	0.9				
Nevada	4	6.0	200,000	7.5	202,400	4.9				
New Mexico	6	9.0	140,300	5.2	187,300	4.6				
Texas	7	10.4	194,400	7.3	207,000	5.0				
C										
Texas	1	1.5	271,000	3.7	293,000	2.5				
Florida	4	5.9	131,000	4.9	131,000	3.2				
Maryland	1	1.5	6,000	0.2	6,000	0.1	1	5.0	5,500	0.6
Oklahoma	1	1.5	20,000	0.8	20,000	0.5				
Oregon	2	3.0	14,000	0.5	36,000	0.8	1	5.0	30,000	3.2
D										
Colorado	1	1.5	198,000	7.4	240,000	5.9				
Indiana							2	10.0	114,400	12.2
New Jersey	2	3.0	12,000	0.5	14,000	0.3	2	10.0	296,000	31.8
Pennsylvania	1	1.5	37,000	1.4	37,000	0.9	1	5.0	64,200	6.9
West Virginia							1	5.0		
Oregon	1	1.5	4,100	0.1	28,500	0.7	1	5.0		
Washington	3	4.5	33,500	1.3	351,500	8.5				
E										
Idaho							3	15.0	3,100	0.3
Michigan							4	20.0	152,100	16.3
Minnesota							2	10.0	230,000	24.6
Wisconsin							2	10.0	39,000	4.2
Wyoming	2	3.0	52,000	1.9	52,000	1.3				
TOTAL	67	100.0	2,676,100	100.0	4,113,400	100.0	20	100.0	934,300	100.0

FIGURE 4
CLIMATIC ZONES AND LOCATIONS OF ON-SITE COMMUNITY AND INDUSTRIAL LAND APPLICATION SURVEY REPORTS



Number Communities / Number Industries x/x

A Mediterranean Climate– Dry summer – mild, wet winter
B Arid Climate – hot, dry
C Humid Subtropical – mild winter hot, wet summer (Wash., Ore., area mild, moist summer)
D Humid Continental – short winter, hot summer
E Humid Continental – long winter, warm summer

SYSTEMS – ON-SITE SURVEY

Casa Grande, Az.
Lake Havasu San. Dist., Az.
Mesa, Az.
Prescott, Az.
Tucson, Az.
Bakersfield, Ca.
Mt. Vernon San. Dist., Bakersfield, Ca.
Las Virgenes Mun. Water Dist., Calabasas, Ca.
Camarillo San. Dist., Ca.
Colton, Ca.
Dinuba, Ca.
Fontana, Ca.
Fresno, Ca.
Hanford, Ca.
Valley San. Dist., Cal.
Rossmoor San., Inc., Laguna Hills, Ca.
Livermore, Ca.
Lodi, Ca.
Irvine Ranch Water Dist., Ca.
Oceanside, Ca.
Ontario, Ca.
Pleasanton, Ca.
Santa Maria, Ca.
San Bernardino, Ca.
Santee County Water Dist., Ca.
San Clemente, Ca.
San Francisco, Ca.
San Luis Obispo, Ca.
Ventura, Ca.
Woodland, Ca.
Colorado Springs, Co.
Walt Disney World, Fl.
Okaloosa County Water & Sewer Dist., Fl.
St. Petersburg, Fl.
Tallahassee, Fl.
St. Charles Utilities, Inc., Md.
Forsgate San. Inc., N.J.
Vineland, N.J.
Alamogordo, N.M.
Clovis, N.M.
Ralton, N.M.
Roswell, N.M.
Santa Fe, N.M.
Santa Fe Airport Rd. Plant, N.M.
Clark County, Nv.
Ely, Nv.
Incline Village, Nv.

Las Vegas, Nv.
Duncan, Ok.
Unified Sewerage Agency, Forest Grove, Or.
Hillsboro, Or.
Milton-Freewater, Or.
Pennsylvania State U., Pa.
Dumas, Tx.
Kingsville, Tx.
LaMesa, Tx.
Midland, Tx.
Monohans, Tx.
San Angelo, Tx.
Uvalde, Tx.
Ephrata, Wa.
Quincy, Wa.
Wala-Wala, Wa.
Cheyenne, Wy.
Rawlins, Wy.
Moulton-Niguel Water Dist., Ca.
Abilene, Tx.
Green Giant Co., Buhl, Id.
Western Farmers Assoc., Aberdeen, Id.
Celotex Corp., Largo, In.
Commercial Solvents, Terre Haute, In.
Chesapeake Foods, Cordova, Md.
Celotex Corp., L'Anse, Mi.

Gerber Products Co., Freemont, Mi.
Michigan Milk Producers Assoc., Ovid, Mi.
Simpson Lee Paper Co., Vicksburg, Mi.
Green Giant Co., Montgomery, Mn.
Stokely Van Camp, Fairmont, Mn.
H.J. Heinz Co., Salem, N.J.
Hunt-Wesson Foods, Inc., Bridgeton, N.J.
U.S. Gypsum Co., Pilot Rock, Or.
Weyerhaeuser Co., Springfield, Or.
Pet Milk Co., Biglerville, Pa.
Howes Leather Co., Frank, W.V.
American Stores Dairy Co., Fairwater, Wi.
Libby, McNeill & Libby, Janesville, Wi.
Idaho Supreme Potato Co., Firth, Id.

TABLE 2
DISTRIBUTION OF COMMUNITIES AND INDUSTRIES SURVEYED ON-SITE BY CLIMATIC ZONE

	Communities						Industries			
	Survey Reports		Population Served				Survey Reports			
Climatic Zone	Number	Percent	Population	Percent	Population Equivalent	Per cent	Number	Percent	Population Equivalent	Percent
A	25	37.3	1,152,300	43.1	1,907,600	46.3				
B	23	34.4	916,200	34.3	1,189,800	28.9				
C	9	13.4	271,000	10.1	293,000	7.2	2	10.0	35,500	3.8
D	8	11.9	284,600	10.6	671,000	16.3	7	35.0	474,600	50.8
E	2	3.0	52,000	1.9	52,000	1.3	11	55.0	424,200	45.4
TOTAL	67	100.0	2,676,100	100.0	4,119,400	100.0	20	100.0	934,300	100.0

in Zones A and B. They include over 77 percent of the population in the 67 communities surveyed. The difference between population equivalent and population provides a measure of the industrial wastes discharged to the community systems. On this basis, the community systems in Zones A and B include an industrial population equivalent of 1,028,900 while the community and industrial systems in Zones C, D and E include a total population equivalent of 1,950,300. Although there were no individual industrial systems surveyed in Zones A and B, these regions include approximately 60 percent of the total population equivalent attributable to industrial wastewaters.

The distribution of wastewater land application systems studied by mail survey appears in Table 3, Distribution of Mail Survey Systems Studied by Climatic Zone. As in the case of the on-site survey, the majority of community systems are located in Zones A and B – approximately 72 percent, or 48 systems. These involve approximately 78 percent of the population of the 67 communities studied. Although the mail survey produced no population equivalent figures for communities, and only broad ranges of population equivalents for industry,

TABLE 3
DISTRIBUTION OF MAIL SURVEY SYSTEMS STUDIED BY CLIMATIC ZONE

	Communities				Industries	
Climatic Regions	No.	(%)	Population	(%)	No.	(%)
A	25	37.4	1,152,300	43.2	–	–
B	23	34.4	916,200	34.5	–	–
C	9	13.5	271,000	10.0	2	10
D	8	12.0	284,600	10.1	7	35
E	2	3.0	52,000	2.0	11	55
TOTALS	67	100.0	2,676,100	100.0	20	100.0

industrial systems were reported in all zones except B. In a manner similar to the on-site survey, industrial systems occur totally in Climatic Zones C, D and E – 100 percent of the 20 systems surveyed.

Discussion. Much of the Southwestern United States relies on irrigation as the basis for its agriculture and other plant growth. Thus, the community installations in Zones A and B probably reflect this need, as well as local attitudes towards water resource conservation in general. The need for supplemental irrigation is confirmed by the reports indicating that land application systems provide the means to water golf courses, highway median strips and other public areas in addition to their use for crop irrigation. Figure 5, Non-Crop Land Application Facilities, contains photographs of typical uses of wastewater in California installations.

In more humid parts of the country, community systems may appear less frequently because these needs and attitudes are less well developed. More available water through greater rainfall would tend to reduce water resource conservation as a public concern. Severe winters also tend to complicate land application system operations and reduce some of the more obvious advantages that might exist for land application in more temperate climates.

The distribution of industrial wastewater land application systems follows a less definitive pattern. The greater number of these systems are located within Zones C, D and E, as contrasted with the water-conscious Southwest. In Zones A and B significant industrial waste loads are discharged to community systems. This probably occurs because local communities in the Southwest may take a more conciliatory attitude about accepting the wastewaters of their hard-won local industries into their own collection and treatment systems. Further, local community control of these industrial wastewaters is consistent with local preferences for water resource management. Figure 6, Industrial Land Application Facilities, contains photographs of industrial facilities in Zones C and D.

Community and Industrial Wastewater Source Information

The distinctions between community and industrial systems generally spring from the basics of function and purpose. Community systems serve the public purposes of a given community and function to dispose of mixed domestic and industrial wastewater effluents. Industrial systems, on the other hand, serve the purposes of one or more industries and function to dispose of primarily industrial effluents.

Table 4, Type of Industry and Climatic Zone Surveyed by On-Site Investigation, depicts the available data on the type and number of the industries in Zones C, D and E. Land application of the wastewaters from fruit and vegetable canning plants – 9 of the 20 systems surveyed – accounts for 71 percent of the population equivalent, 55 percent of the average flow and 55 percent of the area used for application purposes. Wastewaters from milk processing plants, pulp and paper mills and from organic chemical production are also specifically identified. No additional information from the mail survey exists covering this area, due to gaps in the data received.

Of the 67 community land application systems studied in the on-site survey, ten operated prior to 1920. Additional systems have been placed in service during subsequent years at an apparently increasing rate. The earliest industrial system surveyed began operations between 1940 and 1945. One quarter of the industrial systems, however, were installed after 1970. The times at which the community and industrial systems began operations appear in Table 5, Year On-Site Land Application Systems Were Placed in Service by Climatic Zone. Although the number of survey reports developed on the basis of on-site surveys is limited, the information shows a continuing interest in the land application of wastewaters.

Table 6, Distribution of Communities Surveyed On-Site by Number, Population and Climatic Zone, indicates that while 80 percent of the communities appear in the population ranges for 50,000 or less, such systems serve

a. San Bernardino, Cal. spray irrigation of freeway landscaping

b. Ontario, Cal. golf course

FIGURE 5
NON-CROP LAND APPLICATION FACILITIES

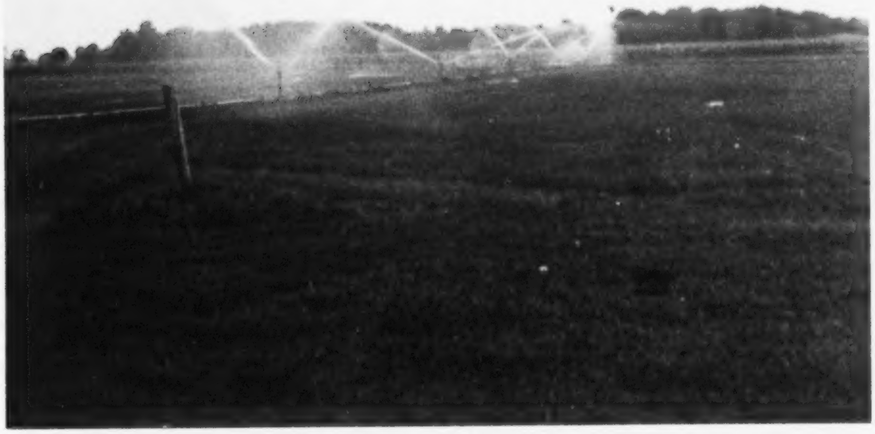
c. Rossmoor, Cal. Irrigation of greenbelt area

FIGURE 5
NON-CROP LAND APPLICATION FACILITIES

a. Commerical solvents spray irrigation facility, Terre Haute, Ind. Fermentation waste applied with average BOD of 30,000 mg/l–year-around basis

FIGURE 6
INDUSTRIAL LAND APPLICATION FACILITIES

b. Hunt-Wesson Foods, Inc., spray irrigation facility, Bridgeton, N.J. Ice builds up on dead weeds during freezing weather. Winter grass remains green throughout most of the winter.



c. Gerber Products Company spray irrigation facility, Freemont, Mich. Frequent mowing has produced a dense turf.

FIGURE 6
INDUSTRIAL LAND APPLICATION FACILITIES

TABLE 4
TYPE OF INDUSTRY AND CLIMATIC ZONE SURVEYED BY ON-SITE INVESTIGATION

Climatic Zone	Type of Industry					
	Canning	Milk	Pulp & Paper	Organic Chemical	Other	Total
C						
Number			1.0	1.00		2.00
Population Equivalent			5,500.0	30,000.00		35,500.00
Flow – MGD			0.5	0.55		1.05
Disposal Area – Acres			75.0	38.00		113.00
D						
Number	3.0			1.00	3.0	7.00
Population Equivalent	360,200.0			106,000.00	8,400.0	474,600.00
Flow – MGD	4.5			0.70	1.4	6.60
Disposal Area – Acres	125.0			110.00	400.0	635.00
E						
Number	6.0	1.00	2.0		2.0	11.00
Population Equivalent	308,200.0	30,000.00	82,900.0		3,100.0	424,200.00
Flow – MGD	5.7	0.25	3.8		1.1	10.85
Disposal Area – Acres	1,059.0	26.00	164.0		170.0	1,419.00
TOTAL						
Number	9.0	1.00	3.0	2.00	5.0	20.00
Population Equivalent	668,400.0	30,000.00	88,400.0	136,000.00	11,500.0	934,300.00
Flow – MGD	10.2	0.25	4.3	1.25	0.7	16.70
Disposal Area – Acres	1,184.0	26.00	239.0	148.00	570.0	2,167.00

only 41 percent of the total population studied. On the other hand, the seven communities investigated with populations in excess of 100,000 provide disposal facilities for 45 percent of the total population. The results of the mail survey appear in Table 7, Distribution of Mail Surveyed Community Systems by Population Ranges. All of the community systems studied by mail survey serve communities with populations of 50,000 or less. Of these, 90 percent serve communities of 25,000 or less and represent 74 percent of the total mail survey population studied. A total of 76 percent of these systems are located in Zones A and B and these areas account for 89 percent of the total population.

A more complete measure of waste loadings appears in Table 8, Distribution of On-Site Surveyed Communities by Number, Population Equivalent and Climatic Zone. Seventy-five percent of the systems have 50,000 population equivalents or less but they provide disposal for only 25 percent of the waste loading based on population equivalents. The ten communities in the over-100,000 class provide treatment for approximately 62 percent of the total population equivalent waste load. Table 9, Distribution of Industries Surveyed On-Site by Number, Population Equivalent and Climatic Zone, demonstrates a similar distribution for industrial population equivalent. The four systems in the over-100,000 class represent land application for almost 64 percent of the total population equivalent waste loading.

TABLE 5
YEAR LAND APPLICATION SYSTEMS WERE PLACED IN SERVICE BY CLIMATIC ZONE – ON-SITE SURVEY

Communities (67)

	Climatic Zone											
	A		B		C		D		E		TOTAL	
Land Application Started	No.	Zone Percent	No.	Zone Percent	No.	Zone Percent	No.	Zone Percent	No.	Zone Percent	No.	Percent of Total
1970-72	1	4.5	1	1.5	3	4.5	1	1.5			6	9.0
1965-69	4	6.0	1	1.5	2	3.0	1	1.5			8	12.0
1960-64	1	1.5	6	6.0	1	1.5	1	1.5			9	13.5
1955-59	5	7.5	3	4.5			1	1.5			9	13.5
1950-54	2	3.0	3	4.5	1	1.5	1	1.5			7	10.5
1945-49	2	3.0	1	1.5			1	1.5			4	6.0
1940-44	1	1.5									1	1.5
1930-39	3	4.5	4	6.0	1	1.5					8	12.0
1920-29			2	3.0							2	3.0
Before 1920	4	6.0	2	3.0	1	1.5	1	1.5	2	3.0	10	15.0
No Data	2	3.0					1	1.5			3	4.5

Industries (20)

Land Application Started	A No.	A Zone Percent	B No.	B Zone Percent	C No.	C Zone Percent	D No.	D Zone Percent	E No.	E Zone Percent	TOTAL No.	Percent of Total
1970-72					1	5.0	2	10.0	2	10.0	5	25.0
1965-69							1	5.0	2	10.0	3	15.0
1960-64							1	5.0	2	10.0	3	15.0
1955-59					1	5.0	1	5.0			2	10.0
1950-54							1	5.0	3	15.0	4	20.0
1945-49									1	5.0	1	5.0
1940-44							1	5.0			1	5.0
1930-39												
1920-29												
Before 1920												
No Data									1	5.0	1	5.0

5

TABLE 6
DISTRIBUTION OF COMMUNITIES SURVEYED ON-SITE BY NUMBER, POPULATION AND CLIMATIC ZONE

	Population Range							
Climatic Zone	**0-5,000**	**5,100-10,000**	**10,100-25,000**	**25,100-50,000**	**50,100-100,000**	**Over 100,000**	**No Data**	**Total**
A								
Number	1	2	8	9	1	4		25
Percent	1.5	3	11.9	13.4	1.5	6.0		37.3
Pop. Equiv.	5,000	18,100	159,000	335,500	100,000	534,700		1,152,300
Percent	0.2	0.7	5.9	12.5	3.7	20.1		43.1
B								
Number	3	4	7	4	2	2	1	23
Percent	4.4	6	4	6	3	3	1.5	34.3
Pop. Equiv.	10,300	33,000	128,900	145,000	126,000	473,000		916,200
Percent	0.4	1.2	5	5.4	4.6	17.6		34.2
C								
Number		3	2	2	2			9
Percent		4.4	3	3	3			13.4
Pop. Equiv.		20,000	30,000	70,000	151,000			271,000
Percent		0.7	1.1	2.6	5.7			10.1
D								
Number	3	2	1	1		1		8
Percent	4.5	3	1.5	1.5		1.5		12
Pop. Equiv.	11,300	13,300	25,000	37,000		198,000		284,600
Percent	0.4	0.5	0.9	1.5		7.4		10.7
E								
Number		1		1				2
Percent		1.5		1.5				3
Pop. Equiv.		10.000		42,000				52,000
Percent		0.4		1.5				1.9
Total								
Number	7	12	18	17	5	7	1	67
Percent	10.4	17.9	26.8	25.4	7.5	10.5	1.5	100.0
Pop. Equiv.	26,600	94,400	342,900	629,500	377,000	1,205,700		2,676,100
Percent	1	3.5	12.9	23.5	14.0	45.1		100.0

Percent values are based on survey total population equivalent.

TABLE 7
DISTRIBUTION OF MAIL SURVEYED COMMUNITY SYSTEMS BY POPULATION RANGES

Climate, No. and Population			Population Ranges – 1,000's			
	0-5	**>5-10**	**>10-25**	**>25-50**	**No Data**	**Total**
A						
Number	14	6	6	3	3	32
Percent	25	10	10	5	5	55
Pop. Equiv.	36,800	42,600	103,000	105,000		287,400
Percent	9	11	26	26		72
B						
Number	8	4	1			13
Percent	14	7	2			23
Pop. Equiv.	24,100	32,100	11,600			67,800
Percent	6	8	3			17
C						
Number	3					3
Percent	5					5
Pop. Equiv.	9,300					9,300
Percent	2					2
D						
Number	2					2
Percent	4					4
Pop. Equiv.	5,700					5,700
Percent	1					1
E						
Number	5	1	1			7
Percent	9	2	2			13
Pop. Equiv.	7,600	8,000	14,000			29,600
Percent	2	2	4			8
Total						
Number	32	11	8	3	3	57
Percent	57	19	14	5	5	100
Pop. Equiv.	83,500	82,700	128,600	105,000		399,800
Percent	21	20	33	26		100

TABLE 8
DISTRIBUTION OF ON-SITE SURVEYED COMMUNITIES BY NUMBER, POPULATION EQUIVALENT AND CLIMATIC ZONE

Climatic Zone	Population Range							
	0- 5,000	5,100- 10,000	10,100- 25,000	25,100- 50,000	50,100- 100,000	Over 100,000	No Data	Total
A								
Number	1	1	7	10	1	5		25
Percent	1.5	1.5	10.4	15	1.5	7.4		37.3
Pop. Equiv.	5,000	10,000	133,000	367,000	100,000	1,292,600		1,927,600
Percent	0.1	0.2	3.2	8.9	2.5	31.5		46.4
B								
Number	2	4	7	3	4	2	1	23
Percent	3	6	10.4	4.4	6	3	1.5	34.3
Pop. Equiv.	6,300	29,400	119,900	105,000	263,600	665.600		1,189,800
Percent	0.2	0.7	2.9	2.5	6.4	16.2		28.9
C								
Number		1	5	1	2			9
Percent		1.5	7.4	1.5	3			13.4
Pop. Equiv.		6,000	86,000	50,000	151,000			293,000
Percent		0.2	2.1	1.2	3.6			7.1
D								
Number	2	2		2			2	8
Percent	3	3		3			3	12
Pop. Equiv.	7,200	15,300		65,500			583,000	671,000
Percent	0.2	0.4		1.6			14.1	16.3
E								
Number		1		1				2
Percent		1.5		1.5				3
Pop. Equiv.		10,000		42,000				52,000
Percent		0.2		1.1				1.3
Total								
Number	5	9	19	17	7	9	1	67
Percent	7.5	13.5	28.2	25.4	10.5	13.4	1.5	100.0
Pop. Equiv.	18,500	70,700	338,900	629,500	514,600	2,541,200		4,113,400
Percent	0.5	1.7	8.2	15.3	12.5	61.8		100.0

TABLE 9
DISTRIBUTION OF INDUSTRIES SURVEYED ON-SITE BY NUMBER, POPULATION EQUIVALENT AND CLIMATIC ZONE

	Population Equivalent							
Climatic Zone	**0-5,000**	**5,100-10,000**	**10,100-25,000**	**25,100-50,000**	**50,100-100,000**	**Over 100,000**	**No Data**	**Total**
C								
Number		1		1				2
Percent		5		5				10
Pop. Equiv.		5,500		30,000				35,500
Percent		0.6		3.2				3.8
D								
Number		1		1	1	2	2	7
Percent		5		5	5	10	10	35
Pop. Equiv.		8,400		39,000	64,200	363,000		474,600
Percent		0.9		4.2	6.9	38.9		50.9
E								
Number	1	1		3	1	2	3	11
Percent	5	5		15	5	10	15	55
Pop. Equiv.	3,100	9,400		108,200	73,500	230,000		424,200
Percent	0.3	1		11.5	7.9	24.6		45.3
Total								
Number	1	3		5	2	4	5	20
Percent	5	15		25	10	20	25	100.0
Pop. Equiv.	3,100	23,300		177,200	137,700	593,000		934,300
Percent	0.3	2.5		18.9	14.8	63.5		100.0

Little difference exists between the distribution of community and industrial population equivalents depicted in Figure 7, Distribution of On-Site Surveyed Community Population and Community and Industry Population Equivalents, except for the 10-25,000 class where there are no industry systems.

The distribution of industrial wastewater land application systems determined through the mail questionnaire survey appear in Table 10, Distribution of Mail Survey Industrial Systems by Ranges of Population Equivalent. As may be noted, insufficiently definitive figures exist for the total population equivalents within each category. This information was not developed from the original mail survey results. As in the case of the on-site surveys, the mail survey industrial systems generally cover all ranges of population equivalents.

Table 11, Distribution of On-Site Surveyed Communities by Flow Population Equivalent and Climatic Zone, and Table 12, Distribution of On-Site Surveyed Industries by Flow, Population Equivalent and Climatic Zone, both indicate the distribution of the systems surveyed by their flow range and climate zone. Of the 60 communities for which on-site survey data are available in this category, approximately 90 percent, serving 73 percent of the total population equivalent, generate flows of 5.0 mgd or less. All of the industrial systems also serve 5.0 mgd, or less. Figure 8, Distribution of On-Site Surveyed Community and Industry Population Equivalent by Flow Ranges, indicates the distribution of the industrial population equivalent for various flow ranges and the concentration of community population equivalent in the 2.6-5.0 mgd class or less.

The results of the mail survey are indicated in Table 13, Distribution of Mail Survey Total Flows by Climatic Zones. It shows the total flows generated by both community and industrial systems. Among the community systems, no total flows exceed 10 mgd and approximately 77 percent of these systems handle flows below 1.5 mgd. Among the industrial systems, flows of up to 10 mgd were identified, but 50 percent of these systems had flows of 1.0 mgd or less.

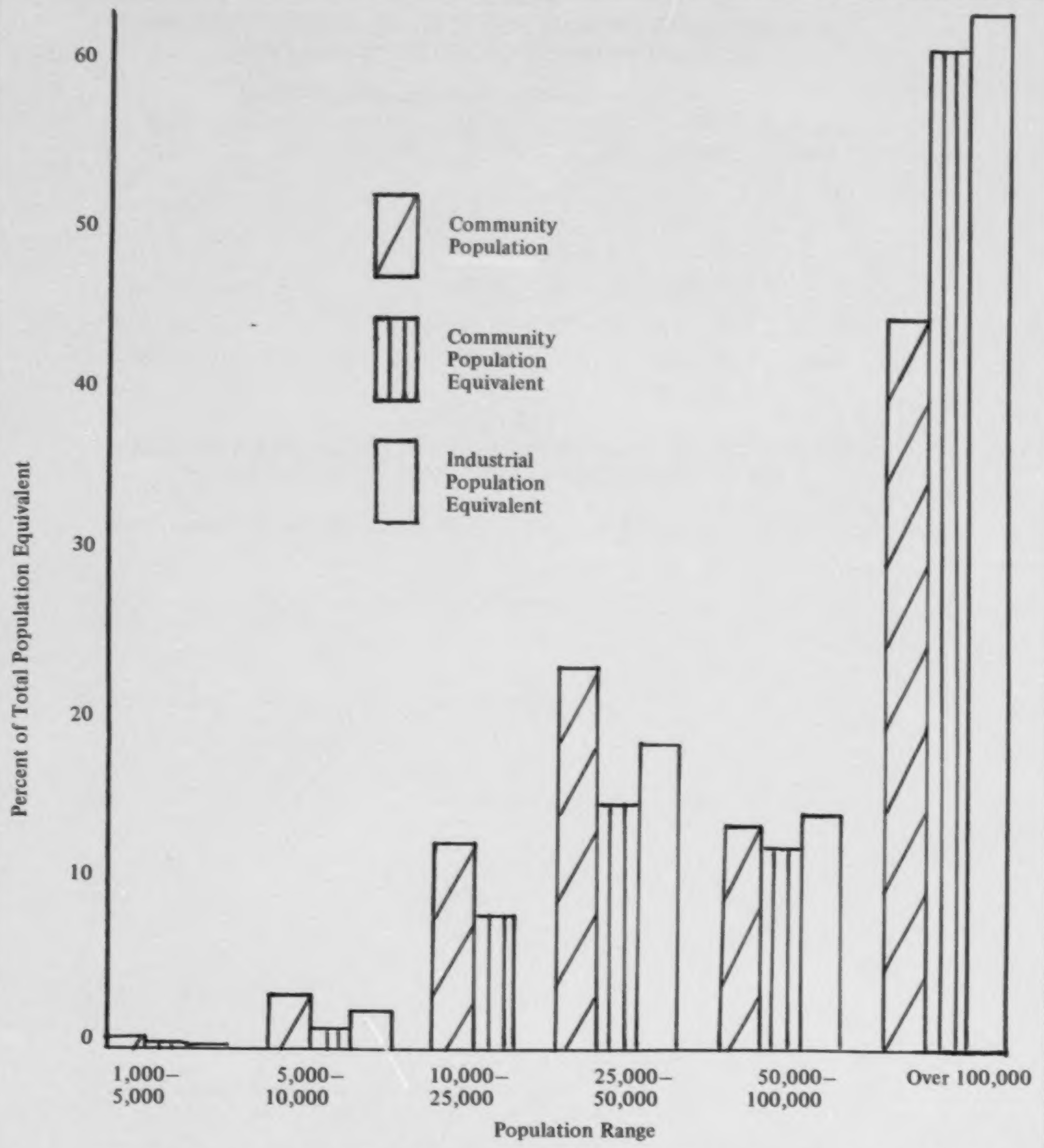


FIGURE 7: DISTRIBUTION OF ON-SITE SURVEYED COMMUNITY POPULATION AND COMMUNITY AND INDUSTRY POPULATION EQUIVALENT

TABLE 10
DISTRIBUTION OF MAIL SURVEY INDUSTRIAL SYSTEMS BY RANGES OF POPULATION EQUIVALENT

Climatic Zone	Population Equivalent Range (x 1,000)											
	0-5		>5-10		>10-25		>25-50		No Data		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A	1	2.8									1	2.8
B	1	2.8									1	2.8
C	1	2.8	1	2.8							2	5.6
D	5	13.9	1	2.8	3	8.3			4	11.1	13	36.1
E	2	5.6	2	5.6	6	16.6	2	5.6	7	19.3	19	52.7
Total	10	27.9	4	11.2	9	24.9	2	5.6	11	30.4	36	100.0

TABLE 11
DISTRIBUTION OF ON-SITE SURVEYED COMMUNITIES BY FLOW, POPULATION EQUIVALENT AND CLIMATIC ZONE

Climatic Zone	Flow Range – MGD								
	0.0-0.5	0.6-1.0	1.1-1.5	1.6-2.5	2.6-5.0	5.1-10.0	Over 10.0	No Data	Total
A									
Number	2	4	4	4	5	1	1	4	25
Percent	3	6	6	6	7.4	1.5	1.5	5.9	37.3
Pop. Equiv.	25,000	280,000	140,000	85,500	907,900	132,500	101,700	235,000	1,907,600
Percent	0.6	6.8	3.4	2.1	22.1	3.2	2.5	5.7	46.4
B									
Number	2	6	1	5	5	2	1	1	23
Percent	3	9	1.5	7.4	7.4	3	1.5	1.5	34.3
Pop. Equiv.	19,400	70,400	6,000	132,500	293,600	190,000	475,600	2,300	1,189,800
Percent	0.5	1.7	0.2	3.2	7.2	4.6	11.5		28.9
C									
Number	4	2		2	1				9
Percent	5.9	3		3	1.5				13.4
Pop. Equiv.	100,000	65,000		28,000	100,000				293,000
Percent	2.4	1.6		0.7	2.4				7.1
D									
Number	3	1	1		2			1	8
Percent	4.5	1.5	1.5		3			1.5	12.0
Pop. Equiv.	46,300	3,200	10,000		268,500			343,000	671,000
Percent	1.1	.01	0.2		6.5			8.4	16.3
E									
Number						1		1	2
Percent						1.5		1.5	3
Pop. Equiv.						42,000		10,000	52,000
Percent						1		0.3	1.3
Total									
Number	11	13	6	11	13	4	2	7	67
Percent	16.4	19.5	9	16.4	19.3	6	3	10.4	100.0
Pop. Equiv.	190,700	418,600	156,000	246,000	1,570,000	364,500	577,300	590,300	4,113,400
Percent	4.6	10.2	3.8	6	38.2	8.8	14	14.4	100.0

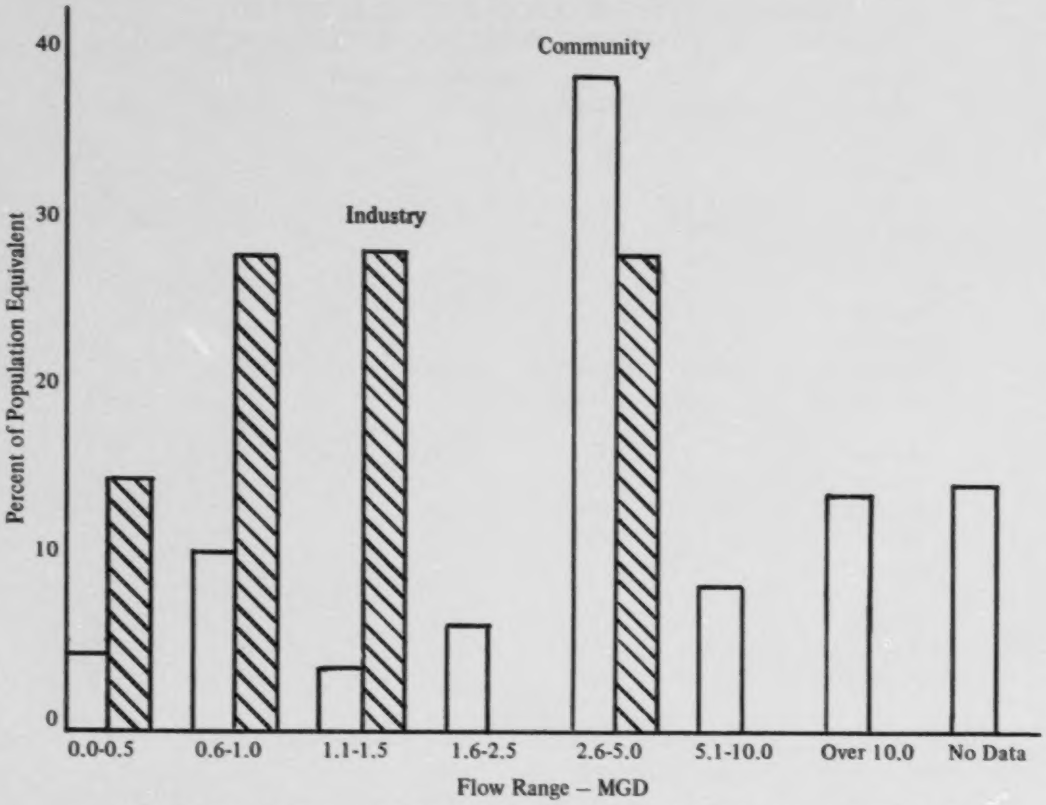


FIGURE 8: DISTRIBUTION OF ON-SITE SURVEYED COMMUNITY AND INDUSTRY POPULATION EQUIVALENT BY FLOW RANGES

TABLE 12
DISTRIBUTION OF ON-SITE SURVEYED INDUSTRIES BY FLOW, POPULATION EQUIVALENT AND CLIMATIC ZONE

Climatic Zone	Flow Range – MGD					
	0.0-0.5	0.6-1.0	1.1-1.5	1.6-2.5	2.6-5.0	Total
C						
Number	1	1				2
Percent	5	5				10
Pop. Equiv.	30,000	5,500				35,500
Percent	3.2	0.6				3.8
D						
Number	3	1	2		1	7
Percent	15	5	10		5	35
Pop. Equiv.	72,600	106,000	39,000		257,000	474,600
Percent	7.8	11.3	4.2		27.5	50.8
E						
Number	3	5	2		1	11
Percent	15	25	10		5	55
Pop. Equiv.	33,100	151,700	230,000		9,400	424,200
Percent	3.5	16.3	24.6		1	45.4
Total						
Number	7	7	4		2	20
Percent	35	35	20		10	100.0
Pop. Equiv.	135,700	263,200	269,000		266,400	934,300
Percent	14.5	28.2	28.8		28.5	100.0

Discussion Existing wastewater land application facilities are used primarily by small communities. In general, the on-site studies investigated systems of larger population and the mail survey covered relatively smaller community systems. The majority of community systems covered by both surveys, however, have populations of 50,000 or less. The size of the industrial systems studied in both surveys appears compatible in all categories.

Wastewater flows are somewhat variable between the two surveys. The mail survey investigated relatively smaller communities, with the result that these flows are generally lower than those of the communities investigated by on-site surveys. Flows for the industrial systems studied are essentially comparable. The majority of flows for both the community and industrial systems are 5.0 mgd or less in all cases.

A conjectural approach to the relative size of the systems encountered suggests that the decision to employ wastewater land application systems among smaller communities and industries may be based upon:

- The need to augment existing treatment facilities to comply with wastewater quality enforcement criteria. This need may exist throughout the year, or as a result of seasonal peak wastewater loadings.
- The relative costs of wastewater effluent land application methods may be more within the reach of small communities and industries than the cost of more traditional methods of treatment plant construction or expansion.
- The use of wastewater land application may be in response to local water resource management needs. The effective use of these effluents in irrigation and for other purposes may afford a means of conserving existing potable, irrigation, and industrial water supplies.

TABLE 13
DISTRIBUTION OF MAIL SURVEY TOTAL FLOWS BY CLIMATIC ZONE

Communities (86)

Flow Range MGD	Zone A No.	Zone A %	Zone B No.	Zone B %	Zone C No.	Zone C %	Zone D No.	Zone D %	Zone E No.	Zone E %	Total No.	Total %
0-0.5	23	26.7	11	12.8	5	5.8	3	3.5	7	8.1	49	56.9
>0.5-1.0	9	10.4	3	3.5					1	1.2	13	15.1
>1.0-1.5	4	4.6									4	4.6
>1.5-2.5	3	3.5									3	3.5
>2.5-5.0	4	4.7	1	1.2					1	1.2	6	7.1
>5.0-7.5	1	1.2									1	1.2
>7.5-10												
>10	1	1.2									1	1.2
No Data	3	3.5	4	4.6					2	2.3	9	10.4
Total	48	55.8	19	22.1	5	5.8	3	3.5	11	12.8	86	100

Industries (35)

Flow Range MGD	Zone A No.	Zone A %	Zone B No.	Zone B %	Zone C No.	Zone C %	Zone D No.	Zone D %	Zone E No.	Zone E %	Total No.	Total %
0-0.5							5	14.2	7	20.0	12	34.2
>0.5-1.0							1	2.9	5	14.2	6	17.1
>1.0-1.5			1	2.9					1	2.9	2	5.8
>1.5-2.5							2	5.8			2	5.8
>2.5-5.0					1	2.9			2	5.7	3	8.6
>5.0-7.5												
>7.5-10	1	2.9									1	2.9
>10					1	2.9	4	11.3			5	14.2
No Data							1	2.9	3	8.5	4	11.4
Total	1	2.9	1	2.9	2	5.8	13	37.1	18	51.3	35	100.0

Wastewater Transport and Treatment Methods

Wastewater Treatment Generally, wastewater treatment occurs prior to the transport of effluents to the land application area. In some cases, additional treatment or storage is also provided at the application site. Table 14, On-Site Surveyed Wastewater Treatment Processes by Climatic Zone, indicates the types of treatment processes used at the central treatment plant prior to transport to the land application site. Approximately one-third of the communities surveyed on-site provide secondary treatment and five percent utilize tertiary treatment processes. Over half of the communities surveyed employ chlorination for disinfection purposes. Sixty percent of the industries surveyed on-site use some form of wastewater screening and approximately 23 percent employ oxidation ponds. No significant regional differences appear for either the community or industrial systems.

Limited data on sludge treatment methods are presented in Table 15, On-Site Survey Sludge Treatment Methods by Climatic Zone. These data cover the 67 percent of the 67 communities surveyed and the 16 percent of the industries surveyed that provided information on this category of information. Sludge digestion and sludge drying represent the methods of treatment that communities use most often. Table 16, On-Site Survey Sludge Disposal by Climatic Zone, indicates that spreading sludge on the ground seems the most commonly identified means of sludge disposal.

No apparent relationship exists between sewer flow and treatment plant capacity for communities or industries, when compared on the basis of climatic zone or treatment plant capacity. Table 17, Relationship Determined by On-Site Survey of Treatment Plant Capacity to Sewer Flow by Climatic Zone, and Table 18, Relationship Determined by On-Site Survey of Treatment Plant Capacity to Sewer Flow as Percent of Sewer Capacity, both show that only 15 percent of the community and industrial systems operate at or above the design capacity of the treatment plant.

TABLE 14
WASTEWATER TREATMENT PROCESSES[1] BY CLIMATIC ZONE – ON-SITE SURVEY

	Climatic Zone					
	A	B	C	D	E	Total
			Communities (67)			
Chlorination	14	8	5	4		31
Primary	2	8	1	3		14
Secondary	23	16	4	2	3	48
Tertiary	1		1	2		4
Oxidation	13	8	2	3	1	27
Other	3			2		5
			Industries (20)			
Screening			1	4	4	9
Primary				1	5	6
Secondary			1			1
Oxidation Ponds				2	3	5
Other				2		2

[1] Many facilities reported the use of more than one process

TABLE 15
ON-SITE SURVEY SLUDGE TREATMENT METHODS[1] BY CLIMATIC ZONE

	A		B		C		D		E		Total	
	Climatic Zone											
	No.	%[2]	No.	%	No.	%	No.	%	No.	%	No.	%
No. of Facilities	25		23		9		8		2		67	
Communities												
Thickening					1	11	2	25			3	4.5
Digestion	9	36	3	13	6		6	75	1	50	25	37.3
Filtration												
Drying	5	20	11	48	3	33	4	50			23	34.3
Other	2	8			2	22	1	13			5	7.5
No Data	12	48	9	39			2	25	1	50	24	35.8
No. of Facilities					2		7		11		20	
Industries												
Filtration									1	9	1	5
Other							1	14	1	9	2	10
No Data					2	100	6	86	9	82	17	85

[1] Many facilities used more than one method

[2] Percentages are of total in climatic zone

TABLE 16
ON-SITE SURVEY SLUDGE DISPOSAL[1] BY CLIMATIC ZONE

Sludge Disposal Method	Climatic Zone											
	A		B		C		D		E		Total	
	No.	%[2]	No.	%	No.	%	No.	%	No.	%	No.	%
No. of Facilities	25		23		9		8		2		67	
Communities												
Tank Truck	2	8			3	33	2	25			7	10.4
Spreading	7	28	7	30	2	22	6	75			22	32.8
Other	4	16	9	39	4	44	2	25			19	28.4
No Data	13	52	8	35	2	22	1	13	2	100	26	38.8
Industries												
No. of Facilities					2		7		11		20	
Tank Truck									1	10	1	5.0
Spreading					1	50	1	14	1	10	3	15.0
Other					2	100	2	29	3	30	7	35.0
No Data							4	57	7	70	11	55.0

[1] Some facilities used more than one method

[2] Percentages are those of the climatic zone

TABLE 17
RELATIONSHIP DETERMINED BY ON-SITE SURVEY OF TREATMENT PLANT CAPACITY TO SEWER FLOW BY CLIMATIC ZONE

Sewer Flow as Percent of Treatment Plant Capacity

Climatic	Less than 25		25-49		50-74		75-99		100		Over 100		No Data		Total	
Zone	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
							Communities									
A			5	7.4	9	13.4	7	10.4	2	3.0	2	3.0			25	37.2
B	1	1.5	3	4.5	6	8.9	6	8.9	2	3.0	3	4.5	2	3.0	23	34.3
C	4	6.0	3	4.5	2	3.0									9	13.5
D	3	4.5	2	3.0							1	1.5	2	3.0	8	12.0
E							1	1.5					1	1.5	2	3.0
Total	8	12.0	13	19.4	17	25.3	14	20.8	4	6.0	6	9.0	5	7.5	67	100.0
							Industries									
C			1	5.0			1	5.0							2	10.0
D	1	5.0	2	10.0	1	5.0	1	5.0					2	10.0	7	35.0
E			1	5.0	1	5.0	2	10.0	3	15.0			4	20.0	11	55.0
Total	1	5.0	4	20.0	2	10.0	4	20.0	3	15.0			6	30.0	20	100.0

TABLE 18
TREATMENT PLANT CAPACITY TO SEWER FLOW AS PERCENT OF SEWER CAPACITY ON-SITE SURVEY

Percent of Treatment Plant Capacity

Capacity	Less than 25		25-49		50-74		75-99		100		Over 100		No Data		Total	
Sewer–MGD	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
							Communities									
0.0-0.5											1	1.5			1	1.5
0.6-1.0					3	4.5	1	1.5	2	3.0	1	1.5			7	10.5
1.1-1.5			1	1.5											1	1.5
1.6-2.5	1	1.5			1	1.5	4	5.9			1	1.5			7	10.4
2.6-5.0	3	4.5	5	7.5	5	7.5	6	8.9	2	3.0	1	1.5			22	32.9
5.1-10.0	3	4.5	4	6.0	4	5.9	1	1.5							12	17.9
Over 10.0	1	1.5	3	4.5	4	5.9	2	3.0			2	3.0			12	17.9
No Data													5	7.4	5	7.4
Total	8	12.0	13	19.5	17	25.3	14	20.8	4	6.0	6	9.0	5	7.4	67	100.0
							Industries									
0.0-0.5	1	5.0	3	15.0			1	5.0	1	5.0					6	30.0
0.6-1.0							1	5.0	1	5.0					2	10.0
1.1-1.5			1	5.0	1	5.0									2	10.0
1.6-2.5			1	5.0	1	5.0	1	5.0							3	15.0
2.6-5.0							1	5.0	1	5.0					2	10.0
No Data													5	25.0	5	25.0
Total	1	5.0	5	25.0	2	10.0	4	20.0	3	15.0			5	25.0	20	100.0

Wastewater Transport Of all the community systems studied by on-site surveys, 55 percent, or 37 systems, employed land application for the final disposal of all their wastewater effluents, as indicated in Table 19, Flow to the Land Application System as a Percent of the Total Community Wastewater Flow by Climatic Zone – On-Site Survey. Ten of the 48 community systems in Zones A and B use the land application system for less than half of their wastewater flow. No apparent relationship exists between total wastewater flow and the percentage of the flow discharged to the land application system as shown in Table 20, Flow to Land Application System as a Percent of the Total Community Wastewater Flow and Total Flow – On-Site Survey. Similar evidence exists through the data accumulated by the mail survey. For the mail survey, 56 percent, or 33 community systems of a total of 59, reported that the land application method is used to dispose of all wastewater effluents. Ten systems, or 17 percent of the total, reported use of land application for the disposal of less than 100 percent of their effluents. Nine are located in Zones A and B. and one is reported in Zone E. A recapitulation of the findings of the mail survey appear as Table 21, Comparison of Average Application Flows to Total Community Flows – Mail Survey.

Communities use various methods to transfer wastewater effluents from the treatment site to the land application site. Table 22, Wastewater Transport to Land Application Site and Climatic Zone for Communities – On-Site Survey, depicts data accumulated by the on-site survey concerning transportation of effluents to land application sites. It shows that over 45 percent of the communities use pressure pipe lines, 28 percent employ gravity pipe lines and approximately 24 percent operate open ditches to transport effluents. Only two communities reported using other methods. Over 60 percent of the communities in Zones C, D and E use pressure pipe lines as compared to 42 percent in Zones A and B. As Table 23, Wastewater Transport to Application Sites and Wastewater Flow for Communities – On-Site Survey indicates, the volume of wastewater does not appear to be a significant factor as to the methods employed for wastewater transport. All of the industrial land application systems covered by the on-site survey use pressure pipe lines to transport their effluents to land application sites.

Wastewater Holding Ponds Holding ponds perform the basic function of flow equalization. They provide some effluent quality stabilization and also effluent storage during periods when flow can not be applied to the land. During the on-site survey, 37 community systems reported the use of wastewater holding ponds. This amounts to 55 percent of the total number of community systems, or 77 percent of the systems for which data on use of holding pond facilities are actually available. Table 24, Holding Pond Volume and Climatic Zone for Communities – On-Site Survey, shows that 19 of the 36 community systems reported the use of holding ponds in Zone A; ten systems provided holding ponds in Zone B. Nine of these Zones A and B holding ponds provide storage in excess of 50 million gallons.

A further attempt to relate storage to climate is depicted in Table 25, Comparison of Holding Pond Storage to Climatic Zone – On-Site Survey. Of the 48 community and industrial systems for which data are available, 37 percent provide storage of 5 days or less. Another 38 percent maintain storage of between 5 and 30 days, and 25 percent in excess of 30 days of storage. Zones A, B and C contain systems in which storage of less than 30 days occurs among 76 percent of the systems reporting. Likewise in Zones D and E, 27 percent of reporting facilities provide storage for 30 days or more. Longer term storage appears more prevalent in the colder climates as opposed to the warmer regions. Figure 9, Holding Ponds, contains photographs of typical holding facilities.

The relationship of holding pond size and average flow is depicted in Table 26, Distribution of Community and Industrial Holding Pond Sizes in Terms of Average Flows to the Application Site – On-Site Survey. Pond sizes in excess of 50 million gallons are used for average flows of 10 mgd and less. Thus, no pattern of maximum pond sizes is apparent from the data. Some criteria for minimum pond sizes do appear, as will be shown below. Table 27, Distribution of Holding Pond Size in Terms of Average Flows to the Application Site – Mail Survey, shows a similar distribution pattern. From this information, basic similarities between the on-site and mail surveys may be deduced. Again, no maximum pond sizing pattern is found. Pond sizes in excess of 50 million gallons are used for flows below 0.5 mgd. Data on minimum pond sizes on the basis of maximum average flows, however, are available. These data for both the on-site and mail surveys appears in Table 28, Comparison of Minimum Computed Holding Pond Storage Times and Pond Size for On-Site and Mail Surveys. In general, the minimum computed storage was found to be higher in the mail survey data than in the on-site survey information. As may be recalled from the analysis of population data, the mail survey information was collected from communities of 50,000 or less while the on-site survey included many communities greater than 50,000. The impact of these larger communities, as well as the effects of sample size may explain this difference. One additional fact should be related concerning the data accumulated through the mail survey – of the 39 community and industrial systems that reported on the use of holding ponds, 36, or 92 percent, indicated that such pond facilities were used. This contrasts with the on-site survey finding that only 75 percent reported the use of ponds.

TABLE 19
FLOW TO LAND APPLICATION SYSTEM AS PERCENT OF TOTAL COMMUNITY WASTEWATER FLOW BY CLIMATIC ZONE – ON-SITE SURVEY

Facility Flow as Percent of Total Wastewater Flow	Climatic Zone A No.	A %	B No.	B %	C No.	C %	D No.	D %	E No.	E %	Total No.	Total %
Less than 25	4	6.0	1	1.5	2	3.0	1	1.5			8	12.0
25-50	3	4.4	2	3.0	2	3.0					7	10.4
51-75			1	1.5	1	1.5					2	3.0
76-99			1	1.5			1	1.5			2	3.0
100	12	17.9	15	22.4	3	4.4	3	4.4	1	1.5	34	50.6
Over 100					1	1.5	2	3.0			3	4.5
No Data	6	9.0	3	4.5			1	1.5	1	1.5	11	16.5
Total	25	37.3	23	34.4	9	13.4	8	11.9	2	3.0	67	100.0

TABLE 20
FLOW TO LAND APPLICATION SYSTEM AS PERCENT OF TOTAL COMMUNITY WASTEWATER FLOW AND TOTAL FLOW – ON-SITE SURVEY

Total Wastewater Flow-MGD	Facility Flow as Percent of Total Wastewater Flow: Less than 25 No.	Less than 25 %	25-50 No.	25-50 %	51-75 No.	51-75 %	76-99 No.	76-99 %	100 No.	100 %	More than 100 No.	More than 100 %	No Data No.	No Data %	Total No.	Total %
0.0-0.5							1	1.5	5	7.4			1	1.5	7	10.4
0.6-1.0									8	11.9	1	1.5			9	13.4
1.1-1.5					1	1.5			6	9.0			1	1.5	8	12.0
1.6-2.5	2	3.0	1	1.5			1	1.5	6	9.0	1	1.5	1	1.5	12	18.0
2.6-5.0	2	3.0	4	5.9	1	1.5			8	11.9			4	6.0	19	28.3
5.1-10.0			1	1.5					1	1.5					2	3.0
Over 10.0	4	5.9	1	1.5							1	1.4	3	4.5	9	13.3
No Data													1	1.5	1	1.5
Total	8	11.9	7	10.4	2	3.0	2	3.0	34	50.7	3	4.4	11	16.5	67	

TABLE 21
COMPARISON OF AVERAGE APPLICATION FLOWS TO TOTAL COMMUNITY FLOW – MAIL SURVEY

Total Flow	Land Application as Percent of Total Flow															
	0-25		26-50		51-75		76-99		100		>100		No Data		Total	
MGD	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-0.5			2	2.3	2	2.3	2	2.3	26	30.2	1	1.2	16	18.6	49	57.0
>0.5-1.0							1	1.2	7	8.1			5	5.8	13	15.1
>1.0-1.5	1	1.2							2	2.3			1	1.2	4	4.6
>1.5-2.5									2	2.3			1	1.2	3	3.5
>2.5-5.0									2	2.3			4	4.6	6	7.0
>5.0-7.5															1	1.2
>7.5-10.0							1	1.2								
>10.0									1	1.2					1	1.2
No Data													9	10.4	9	10.4
Total	1	1.2	2	2.3	2	2.3	4	4.6	40	46.4	1	1.2	36	42.0	86	100.0

TABLE 22
WASTEWATER TRANSPORT TO LAND APPLICATION SITES AND CLIMATIC ZONE FOR COMMUNITIES – ON-SITE SURVEY

Wastewater	Climatic Zone											
	A		B		C		D		E		Total	
Transport Method	No.	%.	No.	%	No.	%	No.	%	No.	%	No.	%
Ditch	10	11.8	7	8.2	1	1.2			2	2.4	20	23.6
Pipeline–Gravity	8	9.4	11	12.9	2	2.4	3	3.5			24	28.2
Pipeline–Pressure	16	18.8	11	12.9	7	8.2	5	5.9			39	45.8
Truck							1	1.2			1	1.2
Other			1	1.2							1	1.2
Total	34	40.0	30	35.2	10	11.8	9	10.6	2	2.4	85	

(All industrial wastewater transport by pressure pipeline.)

[1] Some Communities utilized more than one method of transport

TABLE 23
WASTEWATER TRANSPORT TO APPLICATION SITES AND WASTEWATER FLOW FOR COMMUNITIES – ON SITE SURVEY

	Wastewater Transport Method											
Wastewater	Ditch		Gravity Pipeline		Pressure Pipeline		Truck		Other		Total	
Flow–MGD	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0.0-0.5	3	3.5	4	4.7	13	15.3	1	1.2			21	24.7
0.6-1.0	3	3.5	5	5.9	10	11.8					18	21.2
1.1-1.5	2	2.4	2	2.4	2	2.4					6	7.1
1.6-2.5	5	5.9	6	7.1	4	4.7					15	17.6
2.6-5.0	3	3.5	4	4.7	5	5.9			1	1.2	13	15.3
5.1-10.0	2	2.4	1	1.2	2	2.4					5	5.9
Over 10.0												
No Data	2	2.4	2	2.4	3	3.5					7	8.2
Total	20	23.6	24	28.2	39	45.8	1	1.2	1	1.2	85	

(All industrial wastewater transport by pressure pipeline.)

TABLE 24
HOLDING POND VOLUME AND CLIMATIC ZONE FOR COMMUNITIES – ON-SITE SURVEY

Holding Pond Volume – MG

Climatic	None		0.0-1.0		1.1-5.0		5.1-10.0		10.1-50.0		Over 50.0		No Data		Total	
Zone	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A	3	4.5	1	1.5	4	5.9	2	3.0	6	8.9	6	8.9	3	4.5	25	37.2
B	5	7.5	1	1.5	3	4.5	1	1.5	2	3.0	3	4.5	8	11.9	23	34.4
C	1	1.5			1	1.5	1	1.5	1	1.5	1	1.5	4	5.9	9	13.4
D	2	3.0					1	1.5	3	4.5			2	3.0	8	12.0
E													2	3.0	2	3.0
Total	11	16.5	2	3.0	8	11.9	5	7.5	12	17.9	10	14.9	19	28.3	67	

TABLE 25
COMPARISON OF HOLDING POND STORAGE TO CLIMATIC ZONE – ON-SITE SURVEY

Days of	A, B, & C		D & E		Total	
Storage	No.	%[1]	No.	%	No.	%
0-5	11	33.3	7	46.7	18	37.5
>5-10	8	24.2	2	13.3	10	20.8
>10-15	2	6.1	1	6.7	3	6.2
>15-30	4	12.1	1	6.7	5	10.4
>30	8	24.2	4	26.7	12	25.0
Subtotal	33	100.0	15	100.0	48	100.0
No Data	26		12		38	
Total	59		27		86	

[1] Percentages are of total reporting in groupings of climate zones

TABLE 26
DISTRIBUTION OF COMMUNITY AND INDUSTRIAL HOLDING POND SIZE IN TERMS OF AVERAGE FLOWS TO THE APPLICATION SITE ON-SITE SURVEY

Pond Size MG	>0-0.5		>0.5-1.0		>1.0-1.5		>1.5-2.5		>2.5-5.0		>5.0-10		>10.0		No Data		Total	
None	2	3.0	1	1.5	1	1.5	3	4.4	1	1.5	1	1.5	1	1.5	1	1.5	11	16.4
0-1			1	1.5											1	1.5	2	3.0
>1-5	1	1.5	3	4.4	1	1.5	2	3.0	1	1.5							8	11.9
>5-10			1	1.5	1	1.5	1	1.5	1	1.5					1	1.5	5	7.5
>10-50	3	4.4	2	3.0	1	1.5	3	4.4	3	4.4							12	17.7
>50	1	1.5			1	1.5	1	1.5	4	6.0	1	1.5	1	1.5	1	1.5	10	15.0
No Data	5	7.5	5	7.5	1	1.5	1	1.5	2	3.0	2	3.0	2	3.0	1	1.5	19	28.5
Total	12	17.9	13	19.4	6	9.0	11	16.3	12	17.9	4	6.0	4	6.0	5	7.5	67	

TABLE 27
DISTRIBUTION OF HOLDING POND SIZE[1] IN TERMS OF AVERAGE FLOWS TO THE APPLICATION SITE – MAIL SURVEY

Pond Size MG	Average Flows to Application Site																No Data		Totals	
	0-0.5		>0.5-1.0		>1.0-1.5		>1.5-2.5		>2.5-5.0		>5.0-7.5		>7.5-10.0		>10.0					
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-1	4	3.3			2	1.6			1	0.8							1	0.8	8	6.5
>1-5	4	3.3	2	1.6													4	3.3	10	8.2
>5-10	4	3.3	1	0.8	1	0.8											1	0.8	7	5.7
>10-50	10	8.2	4	3.3			1	0.8	1	0.8							4	3.3	20	16.4
>50	2	1.6	1	0.8			2	1.6									1	0.8	6	4.8
No Data	27	22.1	6	5.0	1	0.8	2	1.6	3	2.5	1	0.8	1	0.8	2	1.6	28	22.2	71	58.4
Total	51	41.8	14	11.5	4	3.2	5	4.0	5	4.0	1	0.8	1	0.8	2	1.6	39	32.2	122	

[1] Includes communit and industry

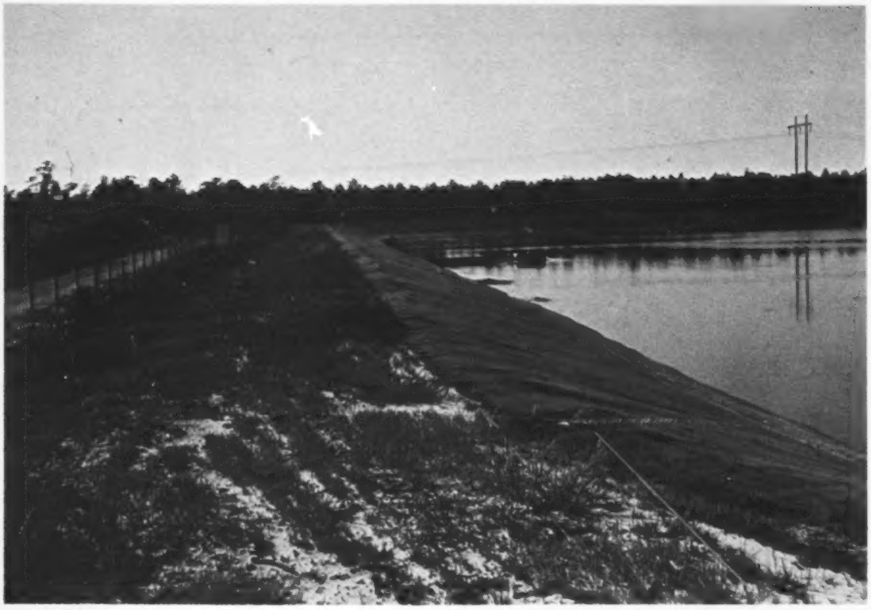
TABLE 28
COMPARISON OF MINIMUM COMPUTED HOLDING POND STORAGE TIMES AND POND SIZES FOR ON-SITE AND MAIL SURVEYS

Pond Size Range MGD	On-Site Survey		Mail Survey	
	Flow Range MGD (Table 26)	Minimum Computed Storage-Days	Flow Range MGD (Table 27)	Minimum Computed Storage-Days
0-1	0.5-1.0	0	0.5-1.0	0
>1-5	>2.5-5.0	1/5	>1.0-1.5	2/3
>5-10	>2.5-5.0	1	>1.5-2.5	2
>10-50	>2.5-5.0	2	>2.5-5.0	2
>50	>5.0-10.0	5	>5.0-10.0	10

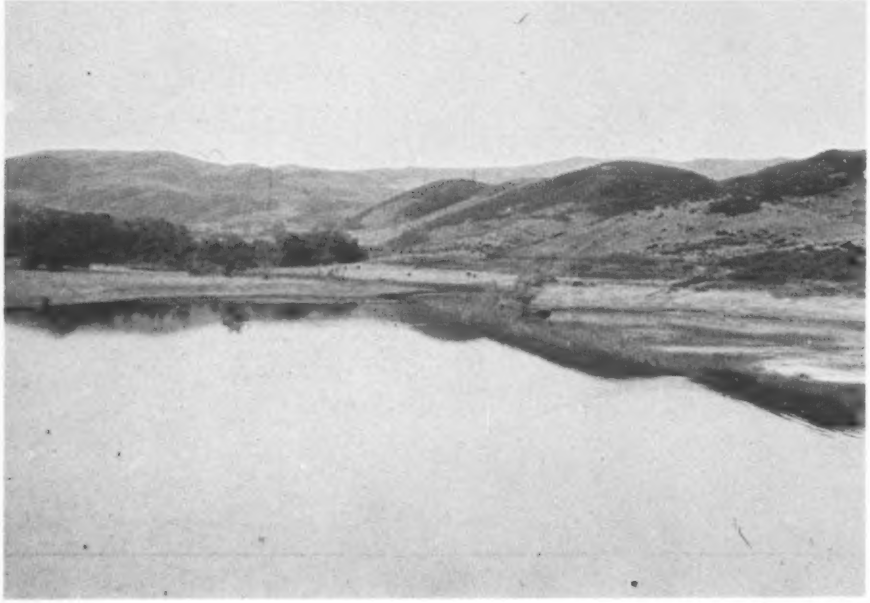
TABLE 29
WASTEWATER TREATMENT[1] AT APPLICATION SITE BY CLIMATIC ZONE ON-SITE SURVEY

Wastewater Treatment at Disposal Site	Climatic Zone										Total	
	A		B		C		D		E			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
	Communities											
Chlorination	13	11.9	3	2.8	4	3.7	6	5.5			26	23.9
Aeration	8	7.3	2	1.8	1	0.9	2	1.8			13	11.8
Other	1	0.9			1	0.9	5	4.6			7	6.4
None	21	19.3	20	18.4	3	2.8			1	0.9	45	41.4
No Data	1	0.9	10	9.2	2	1.8	4	3.7	1	0.9	18	16.5
Total	44	40.3	35	32.2	11	10.1	17	15.6	2	1.8	109	
	Industries											
Chlorination												
Aeration												
Other							5	25	8	40	13	65
None					1	5	1	5			2	10
No Data					1	5	1	5	3	15	5	25
Total					2	10	7	35	11	55	20	

[1] Some facilities reported use of more than one method.

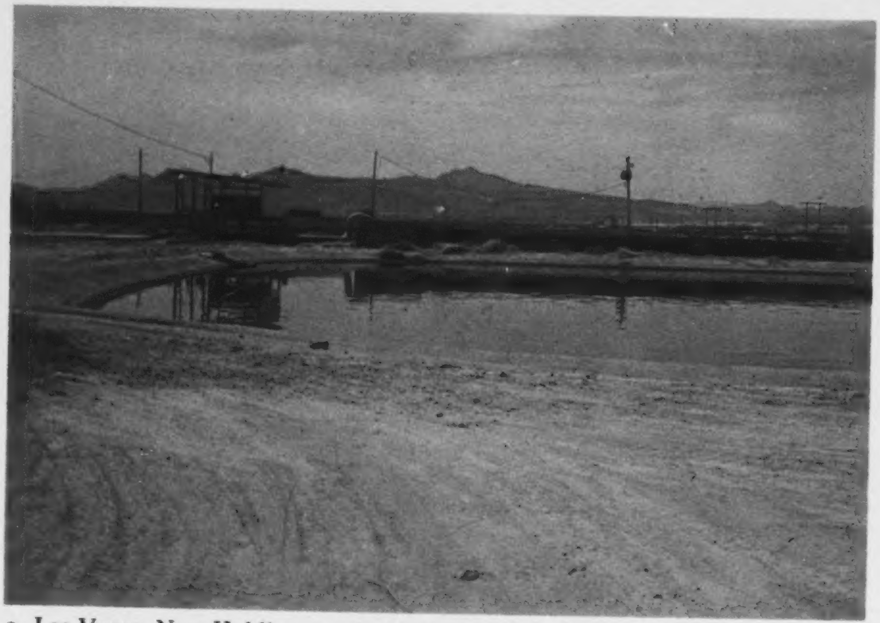


a. Okaloosa County Water and Sewer District. Lined 8-acre holding pond holding pond at Eglin Air Force Base.



b. Irvine, Cal. Large holding reservoir

FIGURE 9
HOLDING PONDS



c. Las Vegas, Nev. Holding pond at treatment plant

FIGURE 9
HOLDING PONDS

Land Application Some form of wastewater treatment is provided by 42 percent of the communities and 65 percent of the industries at the land application sites. This information is presented in Table 29, Wastewater Treatment at Application Site by Climatic Zone – On-Site Survey. Industry systems did not specify their treatment processes. Among communities, however, 24 percent provide chlorination and over 11 percent utilize some form of aeration of their wastewater effluents. Nearly all of the communities in Zones C and D reported chlorination at the land application site. Unfortunately, the on-site survey reports do not indicate whether chlorination is practiced for disinfection or for odor control purposes.

Table 30, Treatment Processes at Treatment Plant Facility and at Application Site – On-Site Survey, indicates that 48 percent of the communities provided wastewater treatment at both the main treatment plant and at the land application site. Of the industries surveyed, 40 percent provided screening at the industrial plant and some additional treatment at the land application site.

Discussion Virtually all of the systems studied by the on-site survey provide some level of treatment of their wastewaters prior to application on the land. Raw wastewaters are not discharged onto land areas. More than half of the communities investigated provide secondary treatment or better. In addition to returning wastewater effluents to the land, a preference for the final disposition of treatment plant sludge onto the land also was disclosed. Most systems are used for the application of all wastewaters onto land sites. Some systems, however, are employed for less than the full wastewater flows generated year-round. In these cases, the use of land application appears to fulfill a seasonal need for the management of wastewaters or to respond to special demands for treated wastewater effluents.

Wastewaters are transported to the application site by means of pressure pipe lines, gravity pipe lines and open channels. The most prevalent method appears to be by

TABLE 30
TREATMENT PROCESSES AT TREATMENT PLANT FACILITY AND AT APPLICATION SITE – ON-SITE SURVEY

Wastewater Treatment Prior to Transfer to Application Site	Wastewater Treatment Facilities at Application Site[1]											
	Aeration		Chlorination		Other		None		No Data		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
	Communities (67)[2]											
Chlorination	3	4.5	13	19.4	2	3.0	4	6.0	16	23.9	38	56.7
None					1	1.5			1	1.5	2	3.0
Primary			1	1.5			1	1.5	11	16.4	13	19.4
Secondary	6	9.0	14	20.9	2	3.0	5	7.5	27	40.3	54	80.6
Tertiary			2	3.0	1	1.5	1	1.5	1	1.5	5	7.5
Oxidation Ponds	4	6.0	6	9.0	4	6.0	5	7.5	13	19.4	32	47.8
Other									2	3.0	2	3.0
	Industries (20)[2]											
Screening					8	40	1	5	2	10	11	55
Primary									2	10	2	10
Secondary							1	5	1	5	2	10
Oxidation Ponds					2	10					2	10
Other					4	20					4	20
No Data									1	5	1	5

[1] Some facilities reported use of multiple facilities.

[2] Percentages are based upon number of facilities surveyed.

pressure pipe line in both community and industry systems.

Most of the land application facilities investigated report the use of holding ponds. The size of holding ponds varies on the basis of climate. Although ponds of all sizes appear in most climatic zones, larger ponds are more common in the colder areas of the country. Average flows do not appear to govern the maximum size of holding ponds, but holding pond storage generally tends to increase with increasing flow.

In many cases additional treatment of wastewaters is provided at the application site, usually in the form of chlorination and/or aeration.

Land Application System Areas And Distribution Methods

Land Application System Areas The size of a land application site is dictated by a variety of important factors – soil characteristics, meteorological conditions, wastewater volume and quality, and the objectives to be fulfilled by the system. Total site area may be taken to mean the area required for the application site itself and for other associated acreage needs – buffer zones, effluent storage areas, treatment sites, roadways, etc.

Table 31, Distribution of On-Site Surveyed Communities by Land Application Area, Population Equivalent and Climatic Zone, indicates, as might be expected, that community land application systems generally increase in area as the population equivalent served increases. Further, differences between dry and humid regions do not prove significant. A less defined trend toward increasing area with increasing population equivalent is shown for industrial systems, as indicated by Table 32, Distribution of On-Site Surveyed Industries by Land Application Area, Population Equivalent and Climatic Zone. The average population equivalent per system appears in Table 33, Average Population Equivalent – On-Site Survey.

The population equivalent for industry systems appears significantly higher than for the corresponding community systems in each area class. The mail survey data shown in

TABLE 31
DISTRIBUTION OF ON-SITE SURVEYED COMMUNITIES BY LAND APPLICATION AREA, POPULATION EQUIVALENT AND CLIMATIC ZONE

	LAND APPLICATION AREA – ACRES					
Climatic Zone	**11-50**	**51-200**	**201-1,000**	**Over 1,000**	**No Data**	**Total**
A						
Number	1	10	9	2	3	25
Percent	1.5	14.9	13.5	3.0	4.5	37.3
Pop. Equiv.	50,000	183,500	535,000	913,100	226,000	1,907,600
Percent	1.2	4.5	13.0	22.2	5.5	46.4
B						
Number	2	9	7	3	2	23
Percent	3.0	13.4	10.4	4.5	3.0	34.3
Pop. Equiv.	20,500	119,100	440,600	556,600	53,000	1,189,800
Percent	0.5	2.9	10.7	13.5	1.3	28.9
C						
Number	4	3		1	1	9
Percent	6.0	4.5		1.5	1.5	13.5
Pop. Equiv.	59,000	83,000		100,000	51,000	293,000
Percent	1.4	2.0		2.4	1.3	7.1
D						
Number	2	2	3			8
Percent	3.0	3.0	4.5			12.0
Pop. Equiv.	13,200	42,300	272,500			671,000
Percent	0.3	1.0	6.6			16.3
E						
Number			1	1		2
Percent			1.5	1.5		2.9
Pop. Equiv.			10,000	42,000		52,000
Percent			0.3	1.1		1.3
Total						
Number	9	24	20	7	7	67
Percent	13.5	35.8	29.7	10.5	10.5	
Pop. Equiv.	142,700	427,900	1,258,100	1,611,700	673,000	4,113,400
Percent	3.5	10.4	30.5	39.2	16.4	

Table 34, Distribution of Total Areas Reserved for Industrial and Community Land Application Systems by Climatic Zone – Mail Survey, corroborate the findings of the on-site survey that there is a negligible impact of climate on total site area. In this case, the data on climatic distribution of system areas are a composite of both community and industrial sites.

A comparison of flow and land application site area is shown in Table 35, Flow and Area Used for Land Application – On-Site Survey. Of the industrial and community systems investigated in the on-site survey, 84 percent employ application areas of from 10 to 1,000 acres. An understandable trend toward increasing land application area with increasing wastewater flow is evident from the data. Similar data developed from the mail survey are presented in Table 36, Distribution of Total Areas Reserved for Land Application

TABLE 32
DISTRIBUTION OF ON-SITE SURVEYED INDUSTRIES BY LAND APPLICATION AREA, POPULATION EQUIVALENT AND CLIMATIC ZONE

	Land Application Area—Acres				
Climatic Zone	**0-10**	**11-50**	**51-200**	**201-1,000**	**Total**
C					
Number		1	1		2
Percent		5	5		10
Pop. Equivalent		5,500	30,000		35,500
Percent		0.6	3.2		3.8
D					
Number	1	4	1	1	7
Percent	5.0	20	5	5	35
Pop. Equivalent		368,600	106,000		474,600
Percent		39.5	11.3		50.8
E					
Number		3	6	2	11
Percent		15	30	10	55
Pop. Equivalent		59,000	135,200	230,000	424,200
Percent		6.3	14.5	24.6	45.4
Total					
Number	1	8	8	3	20
Percent	5.0	40	40	15	
Pop. Equivalent		433,100	271,200	230,000	934,300
Percent		46.4	29.0	24.6	

TABLE 33
AVERAGE POPULATION EQUIVALENT FOR ON-SITE SURVEYED SYSTEMS

	Average Population Equivalent		
	Community		Industry
Area-Acres	**All Regions**	**Zones A & B**	**Zones C, D & E**
0-10			
11-50	15,800	23,500	54,000
51-200	17,800	10,600	34,000
201-1,000	62,900	61,000	76,000
Over 1,000	23,000	284,000	–

TABLE 34
DISTRIBUTION OF TOTAL AREAS RESERVED FOR INDUSTRIAL AND COMMUNITY LAND APPLICATION SYSTEMS BY CLIMATIC ZONE – MAIL SURVEY

Total Area	A		B		C		D		E		Total	
Used–Acres	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-10	7	5.8	5	4.1	1	0.8	2	1.6	4	3.3	19	15.6
>10-50	21	17.2	3	2.5	3	2.5	8	6.6	6	4.9	41	33.6
>50-200	10	8.3	7	5.8	2	1.6	3	2.5	12	9.7	34	27.9
>200-1,000	5	4.1			1	0.8	2	1.6	4	3.3	12	9.8
>1,000												
No Data	6	4.9	5	4.1			1	0.8	4	3.3	16	13.1
Total	49	40.2	20	16.5	7	5.7	16	13.1	30	24.5	122	

TABLE 35
FLOW AND AREA USED FOR LAND APPLICATION–ON-SITE SURVEY
(Community and Industrial Systems–87)

	Total Area–Acres													
Average	0-10		>10-50		>50-200		>200-1,000		>1,000		No Data		Total	
Flows-MGD	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-0.5	1	1.1	8	9.3	7	8.0	1	1.1			1	1.1	18	20.0
>0.5-1.0			4	4.6	13	15.0	1	1.1			1	1.1	19	21.9
>1.0-1.5			2	2.3	3	3.4	2	2.3	1	1.1	1	1.1	9	10.3
>1.5-2.5			1	1.1	5	5.7	6	6.9			1	1.1	13	14.9
>2.5-5			2	2.3	1	1.1	7	8.0	4	4.6	1	2.3	15	17.2
>5-10							2	2.3	1	1.1	1	1.1	4	4.6
>10							1	1.1	1	1.1			2	2.3
No Data					3	4.5	3	3.4			1	1.1	7	8.0
Total	1	1.1	17	19.6	32	36.9	23	26.4	7	8.8	7	8.0	87	

TABLE 36
DISTRIBUTION OF TOTAL AREAS RESERVED FOR LAND APPLICATION PURPOSES BY AVERAGE DAILY FLOWS TO THE APPLICATION SITE – MAIL SURVEY

Average	Total Areas Used–Acres													
Daily	0-10		>10-50		>50-200		>200-1,000		>1,000		No Data		Total	
Flow-MGD	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0.0-0.5	7	5.7	20	16.5	19	15.6	2	1.6			3	2.5	51	41.9
>0.5-1.0	1	0.8	3	2.5	5	4.1	3	2.5			2	1.6	14	11.5
>1.0-1.5	1	0.8	3	2.5									4	3.3
>1.5-2.5			2	1.6			2	1.6			1	0.8	5	4.0
>2.5-5.0	1	0.8					3	2.5			1	0.8	5	4.1
>5.0-7.5							1	0.8					1	0.8
>7.5-10.0					1	0.8							1	0.8
>10.0			1	0.8							1	0.8	2	1.6
No Data	5	4.1	13	10.7	9	7.4	2	1.6			10	8.2	39	32.0
Totals	15	12.2	42	34.6	34	27.9	13	10.6			18	14.7	122	

Purposes by Average Daily Flows to the Application Site – Mail Survey. The community and industrial sites surveyed utilized sites of less than 200 acres in size in 75 percent of the systems and over one-third of all the systems fall into the 10 to 50-acre size range. As pointed out in connection with the on-site survey data, the mail survey information indicates that total area of sites increases with increasing daily flow

The data from the on-site survey indicate that only 27 percent of the communities and 10 percent of the industries use all of the area at the application site for disposal purposes. The balance is for holding ponds, buffer areas and future use, or is not suitable for land application. The range of site utilization is shown in Table 37, Relation of Area Irrigated to Total Land Application Area by Climatic Zone – On-Site Survey. Based on the total area of the disposal site, Table 38, Area Irrigated and Total Land Application Area – On-Site Survey, indicates 13 of the 23 community systems in the 51-200 acre class and 14 of the 17 community systems in the 201-1,000 acre range use at least 75 percent of their available land application area. Eight of the 10 industrial systems in the 51-200 acre class use at least 50 percent of the available area.

A somewhat different evaluation of irrigated area is found in the case of the mail survey data. This approach is represented by the data shown in Table 39, Distribution of Irrigated Acreage to Population and to Average Daily Flows – Mail Survey. The comparison of acreage and population discloses the semblance of a relationship similar to that previously noted for average flows and acreage. It should be noted that the system with the 100,000 or greater population range with an acreage of 10 or less acres has been disregarded in terms of the suggested relationship. The system in question is an industrial installation with a very high-strength waste loading.

TABLE 37
RELATION OF AREA IRRIGATED TO TOTAL LAND APPLICATION AREA BY CLIMATIC ZONE–ON-SITE SURVEY

Area Irrigated as Percent of Total Area

Climatic Zone	Less than 25		25-49		50-74		75-99		100		No Data		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Communities (67)														
A	1	1.5			6	8.9	7	10.4	3	4.5	8	11.9	25	37.2
B					2	3.0	10	14.9	7	10.4	4	6.0	23	34.3
C			2	3.0	1	1.5	1	1.5	4	6.0	1	1.5	9	13.5
D	1	1.5	1	1.5			2	3.0	3	4.5	1	1.5	8	12.0
E							1	1.5	1	1.5			2	3.0
Total	2	3.0	3	4.5	9	13.4	21	31.3	18	26.9	14	20.9	67	
Industries (20)														
A														
B														
C							2	10					2	10
D					4	20	3	15					7	35
E	2	10	2	10	3	15	2	10	2	10			11	55
Total	2	10	2	10	7	35	7	35	2	10			20	

TABLE 38
AREA IRRIGATED AND TOTAL LAND APPLICATION AREA–ON-SITE SURVEY

Area Irrigated as Percent of TotalArea

Total Land Application Area–Acres	Less than 25 No.	Less than 25 %	25-49 No.	25-49 %	50-74 No.	50-74 %	75-99 No.	75-99 %	100 No.	100 %	No Data No.	No Data %	Total No.	Total %
							Communities							
11-50							3	4.5	2	3.0			5	7.5
51-200	1	1.5	3	4.5	3	4.5	7	10.4	6	9.0	3	4.5	23	34.4
201-1,000					3	4.5	6	8.9	8	11.9			17	25.3
Over 1,000	1	1.5			3	4.5	5	7.4	2	3.0	1	1.5	12	17.9
No Data											10	14.9	16	14.9
Total	2	3.0	3	4.5	9	13.5	21	31.2	18	26.9	14	20.9	67	
							Industries							
11-50					1	5	3	15	1	5			5	25
51-200	1	5	1	5	6	30	2	10					10	50
201-1,000	1	5			1	5	2	10	1	5			5	25
Over 1,000														
Total	2	10	1	5	8	40	7	35	2	10			20	

TABLE 39
DISTRIBUTION OF IRRIGATED ACREAGE TO POPULATION AND TO AVERAGE DAILY FLOWS–MAIL SURVEY

Irrigated Acreage – Acres

	0-10 No.	0-10 %	>10-50 No.	>10-50 %	>50-200 No.	>50-200 %	>200-1,000 No.	>200-1,000 %	No Data No.	No Data %	Total No.	Total %
Population (1,000's)												
0-5	8	6.6	20	16.5	10	8.2	2	1.6	24	19.6	64	52.5
>5-10	1	0.8	3	2.5	5	4.1	2	1.6	8	6.6	19	15.6
>10-25	2	1.6	2	1.6	8	6.6	2	1.6	4	3.3	18	14.7
>25-50			3	2.5	1	0.8			1	0.8	5	4.1
>50-100									2	1.6	2	1.6
>100												
No Data	4	3.3	2	1.6	4	3.3			4	3.3	14	11.5
Total	15	12.3	30	24.7	28	23.0	6	4.8	43	35.2	122	
Average Flows–MGD												
0-0.5	8	6.6	15	12.3	14	11.5			14	11.5	51	41.9
>0.5-1.0	2	1.6	2	1.6	7	5.7	2	1.6	1	0.8	14	11.3
>1.0-1.5			2	1.6					2	1.6	4	3.2
>1.5-2.5					2	1.6	1	0.8	2	1.6	5	4.0
>2.5-5.0					2	1.6	2	1.6	1	0.8	5	4.0
>5.0-7.5							1	0.8			1	0.8
>7.5-10.0			1	0.8							1	0.8
>10.0									2	1.6	2	1.6
No Data	5	4.1	10	8.2	3	2.5			21	17.2	39	31.9
Totals	15	12.3	30	24.5	28	22.9	6	4.8	43	35.0	122	

Wastewater Distribution Methods Spray irrigation, overland flow irrigation, and ridge and furrow irrigation appear to be the most widely accepted wastewater land application methods. Spray irrigation involves the controlled spraying of wastewater on the land at a definitive rate. Overland flow provides application of effluents to develop a sheet-flow effect upon the application site. Ridge and furrow irrigation is a commonly used method in the more arid parts of the country for normal crop watering. It involves the flow of effluents through a field tilled to provide furrows with low soil windrows in between.

Community land application systems use spray irrigation at 73 percent of the surveyed on-site installations. Ridge and furrow or other flooding methods are used at 57 percent of the sites. On the other hand, 95 percent of the industrial systems employ spray irrigation. Community and industrial wastewater distribution methods appear in Table 40, Method of Wastewater Application and Climatic Zone – On-Site Survey. A review of the mail survey data presented in Table 41, Method of Wastewater Application and Climatic Zone – Mail Survey, disclose that 4 percent of the community and industrial systems studied use overland flow or ridge and furrow irrigation and over 53 percent employ spray irrigation. Table 42, Summary of Regional Differences in Application Methods for On-Site and Mail Surveys, defines the regional differences in application methods found in the two types of surveys. In both surveys it appears that the prevalent method of application in the more arid parts of the country involves some form of surface distribution. Surface application is consistent with the more traditional methods of irrigation found in Zones A and B due to their long history of crop irrigation. On the other hand, spray irrigation appears to be more prevalent in the more humid parts of the country.

Table 43, Method of Wastewater Application and Land Application Area – On-Site Survey, relates the method of wastewater application to the size of the

TABLE 40
METHOD OF WASTEWATER APPLICATION[1] AND CLIMATIC ZONE–ON-SITE SURVEY

Method of Wastewater Application	Climatic Zone					Total	
	A	B	C	D	E	No.	%[2]
			Communities (67)				
Spray	14	8	9	5	1	37	55.2
Flooding	9	11		2	2	24	35.8
Ridge and Furrow	7	7				14	20.9
Other	1	2	1			4	6.0
No Data		3		1		4	6.0
Total	31	31	10	8	3	83	
			Industries (20)				
Spray			2	7	10	19	95
Ridge and Furrow					1	1	5
Total			2	7	11	20	

[1] Some communities utilize more than one method

[2] Percentages are of total communities surveyed

TABLE 41
METHOD OF WASTEWATER APPLICATION[1] AND CLIMATE REGION – MAIL SURVEY

Climatic Zone	Spray Irrigation		Overland Flow		Ridge & Furrow		Other		None		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A	26	20.2					10	7.8	17	13.2	53	41.2
B	9	7.0					5	3.9	8	6.2	22	.17.1
C	3	2.3							2	1.5	5	3.8
D	12	9.3	1	0.8	1	0.8	1	0.8	3	2.3	18	14.0
E	19	14.6			3	2.3	1	0.8	8	6.2	31	29.9
Total	69	53.4	1	0.8	4	3.1	17	13.3	38	29.4	129	100.0

[1] Some jurisdictions use more than one method

TABLE 42
SUMMARY OF REGIONAL DIFFERENCES IN APPLICATION METHODS FOR ON-SITE AND MAIL SURVEY

	On-Site		Mail	
Climatic Zone	Spray %[1]	Surface %	Spray %	Surface %
A,B	39.4	87.2	51.0	68.2
C,D,E	60.6	12.8	49.0	31.8

[1] Percentages are of total facilities using method.

TABLE 43
METHOD OF WASTEWATER APPLICATION[1] AND LAND APPLICATION AREA – ON-SITE SURVEY

Method of Wastewater Application	Land Application Area–Acres							
	0-10	11-50	51-200	201-1,000	Over 1,000	No Data	Total No.	Total %[2]
	Communities (67)							
Spray		5	14	15		3	37	55.2
Flooding			4	10	5	5	24	35.8
Ridge and Furrow		1	6	3	2	2	14	20.9
Other		1	1	1	1		4	6.0
No Data				1	1	2	4	6.0
Total		7	25	30	9	12	83	
	Industries (20)							
Spray	1	8	7	3			19	95.0
Ridge and Furrow			1				1	5.0
Total	1	8	8	3			20	

[1] Some communities reported more than one method of application

[2] Percentages are of total surveyed communities

TABLE 44
WASTEWATER APPLICATION METHODS COMPARED TO SOIL TYPES AND GROUND COVER–MAIL SURVEY[1]

Soil Type	Spray Irrig.	Overland Flow	Ridge Furrow	Other	No Data	Total No.	Total %[2]
Loam	31			6	13	50	41.0
Silt	13			2	1	16	13.1
Clay	21		2	6	7	36	29.5
Sand	25		1	6	13	45	36.9
Gravel	11		1		8	20	16.4
Other	1					1	0.8
No Data	8	1	1	3	12	25	20.5
Total	110	1	5	23	54	193	
Cover							
Grass	44	1	4	4	10	63	51.6
Forest	5				2	7	5.7
Crops	12			8	1	21	17.2
No. Cult.	11			2	4	17	13.9
No Veg.	6			2	4	12	9.8
No Data	15			3	23	41	33.6
Totals	93	1	4	19	44	161	

[1] Many communities and industries utilized more than one method of ground cover

[2] Percentages are of number of facilities surveyed

Additional topographic information would be required to determine why specific application methods are used in preference to others.

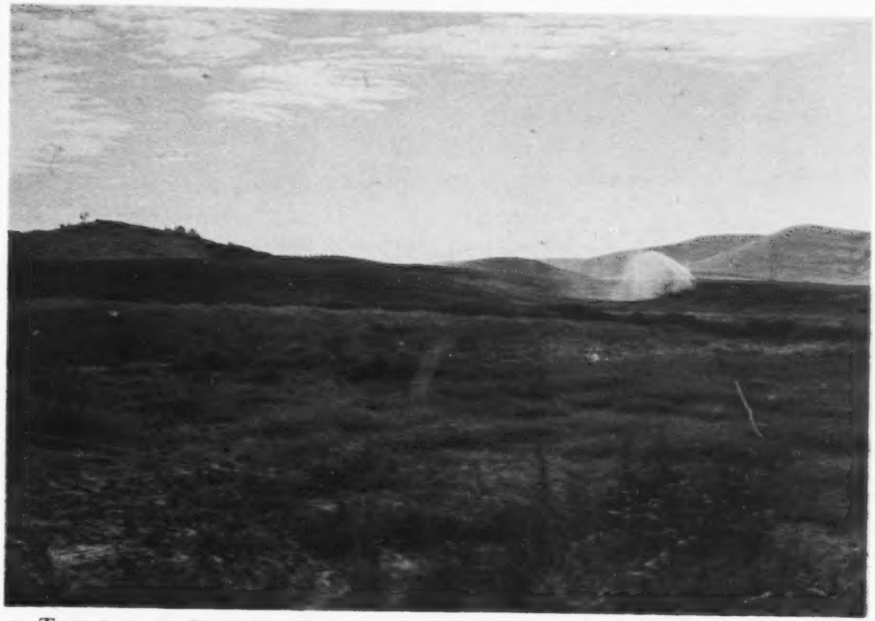
Table 44, Wastewater Application Methods Compared to Soil Types and Ground Cover – Mail Survey, relates soils and ground cover to wastewater application methods. It appears that all methods of wastewater application have been used with all types of soils and with all types of ground cover. The preferences in application methods for specific soil types and ground covers appears in Table 45, Summary of Application Methods in Terms of Soil Types and Ground Cover – Mail Survey. For soils of loam, silt and clay, spray distribution is used more extensively than surface application. With more granular soils, spray irrigation is utilized more equally in comparison with surface application. Surface irrigation is used most often in grass and forest covers, and for crop lands.

application area. The type of distribution system shows the following trend towards surface application on larger application area:

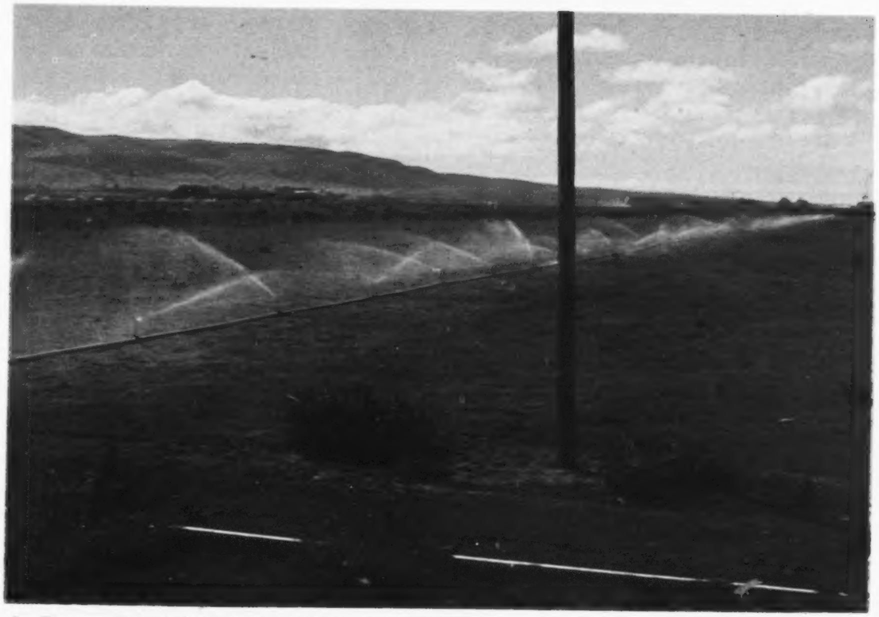
Application Area	Spray	Surface
Less than 50 acres	50%	22%
50-200	46%	42%
200-1,000	48%	45%
Over 1,000	0	100%

Figure 10, Spray System, is a photograph of a large turret spray at Rossmoor, California, and a portable row of sprinklers at Santa Maria, California.

For the smallest application areas, spray systems appear to be used about twice as often as surface methods. In the intermediate size ranges both systems experience almost equal usage, and all of the larger application systems employ surface distribution. In the on-site survey, flooding is utilized for twice as many systems as the ridge and furrow method – in 21 systems compared to 12.



a. Turret spray, Pomona, Cal.



b. Row of sprinklers, Santa Monica, Cal.

FIGURE 10
SPRAY SYSTEMS

TABLE 45
SUMMARY OF APPLICATION METHODS IN TERMS OF SOIL TYPES AND GROUND COVER – MAIL SURVEY

	Spray		Surface	
Soil Type	**No**	**%**	**No.**	**%**
Loam, silt, clay	65	62.7	37	56.1
Sand, gravel	36	35.2	29	43.9
Other	1	0.1	0	
Total	102		66	
Ground Cover				
No planted cover	17	21.8	12	28.6
Grass	44	56.4	19	45.2
Crops	12	15.4	9	21.4
Forest	5	6.4	2	4.8
Total	78		42	

Discussion The foregoing evaluation of survey findings has attempted to deal with two important features of the wastewater land application process – system areas and wastewater distribution methods. Generally, the size of land application sites vary approximately with population equivalents, and even more directly with wastewater flow and flow related factors such as community population. Population equivalent provides an important measure of industrial contribution, but it performs a more important role as a measure of industrial wastewater strength and flow – the primary factor influencing site acreage.

Industrial wastewaters disposed of through the land application process appear to be of higher original strength than do community wastewaters. In these terms, industries impose a much higher original quality loading per acre than do communities employing similarly sized sites. Climate proved to influence disposal site size in a negligible manner, or not at all, primarily because few facilities in cold weather areas operate on a year-round basis.

Disposal Field Characteristics

One of the most important considerations involved in wastewater land application concerns the disposal field itself. The effectiveness of the system depends upon the capacity of the field to receive wastewaters, and enhance their quality without producing deleterious effects upon local ecology and environment. Local soil conditions, groundwater, land slope and the types of vegetative covers employed are some of the determinants of site capacity. The following will attempt to describe some of these important site characteristics within the limits of the available data.

Soil Conditions The on-site survey of industrial and community land application systems indicates that the predominant soil types utilized in all climatic zones are sand, loam and clay. Climatic zone does not appear to influence the soil types involved. Table 46, Soil Types in Land Application Areas by Climatic Zone – On-Site Survey, presents the distribution of soil types among community and industry systems. Many of the community disposal sites utilize multiple types of soil for effluent application. Approximately 91 percent of the listed systems apply wastewaters to loams, silts or clays, and approximately 72 percent operate application fields in the granular materials – sand and gravel. Eighteen of the listed industrial systems utilize application fields composed of loams, silts or clays. Nine industrial application fields are composed of sands and gravels. A composite table of industrial and community disposal systems

TABLE 46
SOIL TYPES[1] IN LAND APPLICATION AREAS BY CLIMATIC ZONE
ON-SITE SURVEY

Soil Types	A	B	C	D	E	Total No.	Total %[2]
				Communities			
Loam	10	13	5	2		30	44.8
Silt	5	4	1	1		11	16.4
Clay	10	4	2	3	1	20	29.8
Sand	15	12	5	5		37	55.2
Gravel	3	6		1	1	11	16.4
Other		1				1	1.5
No Data		2		1		3	4.5
Total	43	42	13	13	2	113	
				Industries			
Loam			2	5	6	13	65
Silt				3	5	8	40
Clay				1	1	2	10
Sand				3	4	8	40
Gravel			1	1		1	5
Other					1	1	5
No Data					1	1	5
Total			3	13	18	34	

Climatic Zone

[1] Some facilities reported more than one type of soil.

[2] Percentages are of total surveyed facilities.

developed from the mail survey appears as Table 47, Soil Types Reported at Existing Land Application Areas – Mail Survey. These data agree in general with the findings of the on-site survey that the prevalent types of application field solids encountered are sand, loam and clay. The mail survey data covering community and industrial application from fields, with 180 soil types mentioned, indicate that 74 percent of the fields contain loams, salts and clays and 55 percent contain sands and gravels.

No apparent relationship exists between soil type and wastewater flow, as shown in Table 48, Classification by Soil Type and Flow – On-Site Survey. The low wastewater application rates do not appear to be influenced by soil type, as indicated in Table 49, Classification by Soil Type and Wastewater Application Rate – On-Site Survey. This influence may be masked by the limited number of systems surveyed.

TABLE 47
SOIL TYPES REPORTED[1] AT EXISTING LAND APPLICATION AREAS–MAIL SURVEY

Soil Type	Number of Systems	% of Total[2]
Loam	45	36.9
Silt	14	11.5
Clay	31	25.4
Sand	46	37.7
Gravel	21	17.2
Other	1	0.8
No Data	22	18.0
Total	180	

[1] Many facilities reported more than one soil type.

[2] Percentages are of total facilities.

TABLE 48
CLASSIFICATION BY SOIL TYPE AND FLOW–ON-SITE SURVEY[1]

	Soil Type								
Flow-MGD	**Loam**	**Silt**	**Clay**	**Sand**	**Gravel**	**Other**	**No Data**	**Total**	
				Communities (67)				**No.**	**%[2]**
0.0-0.5	3	1	4	3	1	1		14	20.9
0.6-1.0	6	5	4	11	2			27	40.3
1.1-1.5	2	1	1	5				9	13.4
1.6-2.5	8	1	3	9	2			23	34.3
2.6-5.0	6	1	2	5	1		2	17	25.4
5.1-10.0	1	1	1		3			6	8.9
Over 10.0	2		3	2				7	10.4
No Data	2	1	2	2	2		1	10	14.9
Total	30	11	20	37	11	1	3	113	
				Industries (20)					
0.0-0.5	6	3		1		1		11	55
0.6-1.0	5	3	1	4				13	65
1.1-1.5	2	2	1	1	1		1	8	40
1.6-2.5									
2.6-5.0				2				2	10
5.1-10.0									
Over 10.0									
No Data									
Total	13	8	2	8	1	1	1	34	

[1] Some facilities reported more than one soil type. [2] Percentages are of facilities surveyed.

TABLE 49
CLASSIFICATION BY SOIL TYPE[1] AND WASTEWATER APPLICATION RATE–ON-SITE SURVEY

Wastewater				Soil Type				
Application	**Loam**	**Silt**	**Clay**	**Sand**	**Gravel**	**Other**	**Total**	
Rate–in./day				**Communities (67)**			**No.**	**%[2]**
0.0-0.10	7	1	2	5	1	1	16	23.9
0.11-0.25	5	2	5	6	4		22	32.8
0.26-0.50	8	1	4	6	1		21	31.3
0.51-1.00	2	1	1	3	1	1	9	13.4
Over 1.00		1	2	7	2		12	17.9
No Data	8	5	6	10	2	2	33	49.3
Total	30	11	20	37	11	4	113	
				Industries (20)				
0.0-0.10	1					1	2	5
0.11-0.25	6	3	2	3	1	2	17	85
0.26-0.50	4	4		2			10	50
0.51-1.00	2	1		1			4	20
Over 1.00				2			2	10
No Data								
Total	13	8	2	8	1	3	35	

[1] Some facilities reported more than one soil type [2] Percentages are of facilities surveyed

Groundwater Table Depth and Underdrains A total of 122 separate community and industrial mail survey responses were reviewed to determine the effects of groundwater on disposal field selection and operation. The results of this study are presented in Table 50, Groundwater Table Depth Encountered in Existing Land Application Sites – Mail Survey. Only 19 percent of the existing systems surveyed had groundwater depths of 10 feet or less. This suggests that groundwater depth may have been one of the important factors considered in the selection of land application sites.

Underdrains perform the function of controlling groundwater levels and of collecting the mixture of land-applied wastewaters and groundwaters for use for other purposes or for discharge into receiving waters. The mail survey indicated the existence of underdrains in some disposal fields but did not indicate their true purpose or use.

In the mail survey study of 122 wastewater disposal fields, only 6 of these systems, or 49 percent of the total, employed underdrains. Table 51, Use of Underdrains – Mail Survey, presents this basic information. Of the 23 systems reporting groundwater levels located 10 feet or less from the surface, only 6 systems specifically reported use of underdrains. Thus underdrains apparently are being used to control groundwater levels, where necessary, and to minimize groundwater interference with the land application process. Table 52, Use of Underdrains by Soil Type – Mail Survey, shows the soil types in which underdrains have been used. The uniform distribution indicates that installation of such underdrains to overcome actual or potential groundwater interference has occurred in all soil types.

TABLE 50
GROUNDWATER TABLE DEPTH ENCOUNTERED IN EXISTING LAND APPLICATION SITES – MAIL SURVEY

Groundwater Depth	Number of Systems	% of Total
0-10	23	19
10-25	16	13
25-50	13	10
50-100	8	7
100	16	13
No Data	46	38
Total	122	

TABLE 51
USE OF UNDERDRAINS
MAIL SURVEY

	Systems	Percent of Total
Underdrains	6	4.9
No underdrains	75	61.5
No Data	41	33.6
Total	122	

TABLE 52
USE OF UNDERDRAINS BY SOIL TYPE[1]
MAIL SURVEY

Soil Type		Systems
Loam		2
Silt	**2**	2
Clay	**2**	2
Sand	**1**	1
Gravel	**2**	2
No Data	**1**	1
Total		10

[1] Some facilities reported presence of more than one type of soil

TABLE 53
CLASSIFICATION BY GROUND COVER[1] AND CLIMATIC ZONE – ON SITE-SURVEY

	Climatic Zone					Total	
Ground Cover	**A**	**B**	**C**	**D**	**E**	**No.**	**%[2]**
			Communities (67)				
Grass	16	7	4	3		30	44.8
Forest	3		4	1		38	11.9
Crop	13	16	3	2		36	53.7
No Vegetation				1		2	3.0
No Data	1	1		3		5	7.5
			Industries (20)				
Grass			2	7	8	17	85
Forest				1		1	5
Crop					3	3	15
No Vegetation				1		1	5
Not Cultivated					1	1	5
No Data					1	1	5

[1] Some facilities utilized more than one type of ground cover

[2] Percentages are of total communities and industries surveyed

TABLE 54
LAND COVER PRACTICE BY TYPE OF SYSTEM MAIL SURVEY[1]

	Community		Industrial		Total	
	No.	**%**	**No.**	**%**	**No.**	**%**
No Vegetation	8	11.1	3	8.3	11	10.2
No Cultivation	14	19.4	2	5.6	16	14.8
Grass	27	37.5	29	80.5	56	51.8
Crops	18	25.0			18	16.7
Forest	5	7.0	2	5.6	7	6.5
Total	72		36		108	
No Data	14				14	

[1] Percentages are based upon number of facilities by type

Application Field Ground Cover Grass and crops appear to be the predominant types of ground cover in community land application systems evaluated in the on-site survey. Grass represents the major ground cover employed for industrial application fields. These data appear in Table 53, Classification by Ground Cover and Climatic Zone – On Site Survey. A summary of similar data on application field ground cover also appears in Table 44, Wastewater Application Methods Compared to Soil Types and Ground Cover – Mail Survey. Data from the mail survey covered both community and industrial systems and indicated that among the 160 systems reported (41 gave no data), the most commonly used ground cover was grass. Grass ground cover was used in 52 percent of the systems; 24 percent of the systems reported no vegetation, or at least no cultivation; 17 percent reported the use of wastewater effluents for crop irrigation; and only 6

TABLE 55
GROUND COVER AND WASTEWATER FLOW–ON-SITE SURVEY

Wastewater Flow-MGD	Grass	Forest	Crop	Ground Cover [1] No Vegetation	Ground Cover [1] Not Cultivated	No Data	Total No.	Total % [2]
				Communities (67)				
0.0-0.5	8	3	2			1	14	20.9
0.6-1.0	9	3	3			1	16	23.9
1.1-1.5	2		3	1			6	9.0
1.6-2.5	2	2	10				14	20.9
2.6-5.0	5		9	1		2	17	25.4
5.1-10.0			2				2	3.0
Over 10.0	1		2			1	4	6.0
No Data	3		5				8	11.9
				Industries (20)				
0.0-0.5	6					1	7	35
0.6-1.0	6	1	1	1	1		10	50
1.1-1.5	4		1				5	25
1.6-2.5								
2.6-5.0	1		1				2	10

[1] Some facilities utilized more than one type of ground cover

[2] Percentages are of total communities and industries surveyed

TABLE 56
COMPARISON OF GRASS AND CROP USAGE IN TERMS OF FLOW – ON-SITE SURVEY

Wastewater Flow–MGD	Percent of Systems Grass	Percent of Systems Crop
Less than 1.0	28	6
Over 1.0	17	31

percent applied wastewaters to irrigate forested areas.

A recapitulation of disposal field cover usage by system type is presented in Table 54, Land Cover Practice by Type of System – Mail Survey. In general, a similar distribution of land cover types was found in both community and industrial systems, except for the heavier predominence of grass cover in industrial sites. Thus, with this one variant, there are no apparent preferences for one type of cover over another on the basis of system type – community or industrial.

Table 55, Ground Cover and Wastewater Flow – On-Site Survey, indicates that community systems use grass as the predominant ground cover for flows less than one mgd and crops as ground cover for higher rates of flow. The comparison of the use of grass and crops in terms of flow is tabulated in Table 56, Comparison of Grass and Crop Usage in Terms of Flow – On-Site Survey.

Discussion The predominant soil types utilized in all climatic zones appear to be sand, loam and clay. The analysis of soil types in terms of climate and wastewater flow indicate that past practice in application field site selection was influenced more strongly by other local factors than soil conditions.

Site selection apparently considers groundwater table depth very carefully. Only a few systems reported groundwater interference with land application operations. These systems also indicated the use of underdrains to control groundwater.

Land Application System Operations

Continuity of Operations The continuity of wastewater land application concerns the number of months during the year and the number of days per week that the system operates. Continuity provides one basis for operational evaluation of the current practices in land application. As shown in Table 57, Months per Year Land Application Systems

TABLE 57
MONTHS PER YEAR LAND APPLICATION SYSTEMS OPERATED BY CLIMATIC ZONE – ON-SITE SURVEY

	Climatic Zone											
Months/Year	A		B		C		D		E		Total	
System Operated	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
					Communities							
1											–	
2											–	
3											–	
4					2	3.0					2	3.0
5											–	
6	1	1.5			1	1.5	1	1.5			3	4.5
7	3	4.5	3	4.5	1	1.5	1	1.5			8	17.0
8	1	1.5									1	1.5
9	1	1.5	2	3.0							3	4.5
10			1	1.5							1	1.5
11					1	1.5					1	1.5
12	19	28.3	14	20.9	4	6.0	5	7.4	2	3.0	44	65.6
No Data			3	4.4			1	1.5			4	5.9
Total	25	37.3	23	34.3	9	13.5	8	11.9	2	3.0	67	
					Industries							
1												
2									1	5	1	5
3					1	5	1	5			2	10
4									1	5	1	5
5									2	10	2	10
6									1	5	1	5
7							1	5	1	5	2	10
8											–	
9							1	5	1	5	2	10
10											–	
11									1	5	1	5
12					1	5	4	20	3	15	8	40
No Data												
Total					2	10	7	35	11	55	20	

TABLE 58
MONTHS OF YEAR LAND APPLICATION SYSTEMS OPERATED BY CLIMATIC ZONE – MAIL SURVEY

Months Operated	Climatic Regions A		B		C		D		E		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Communities												
1												
2	2	2.3									2	2.3
3									1	1.2	1	1.2
4			2	2.3							2	2.3
5					1	1.2			2	2.3	3	3.5
6												
7	1	1.2	1	1.2					1	1.2	3	3.6
8	1	1.2									1	1.2
9												
10	2	2.3									2	2.3
11	1	1.2									1	1.2
12	30	34.8	12	14.0	4	4.6	3	3.5	5	5.8	54	62.8
No Data	11	12.8	4	4.6					2	2.3	17	19.7
Total	48	55.8	19	22.1	5	5.8	3	3.5	11	12.8	86	
Industries												
1												
2									2	5.6	2	5.6
3							1	2.8	2	5.6	3	8.4
4					1	2.8	1	2.8	6	16.6	8	22.2
5							1	2.8			1	2.8
6												
7									1	2.8	1	2.8
8							1	2.8	1	2.8	2	5.6
9							2	5.6	1	2.8	3	8.4
10												
11												
12	1	2.8	1	2.8	1	2.8	5	13.7	5	13.7	13	35.8
No Data							2	5.6	1	2.8	3	8.4
Total	1	2.8	1	2.8	2	5.6	13	36.1	19	52.7	36	

Operated by Climatic Zone – On-Site Survey, approximately 66 percent of the community systems and 40 percent of the industrial systems operate throughout the year. Similar results occur on the basis of the mail survey. Table 58, Months of Year Land Application Systems Operated by Climatic Zone – Mail Survey, shows that 63 percent of the community systems and 36 percent of the industrial systems surveyed operate on a full-year basis. A comparison of regional differences for both the on-site and mail surveys appears in Table 59, Comparison of Full-Year Operations for Both On-Site and Mail Surveys.

Grass was found to be the predominant type of ground cover among the systems surveyed, for flows of 1 mgd or less, with crops utilized for higher flows. A comparison of ground cover types in terms of climate suggests that forest irrigation occurs more often in humid regions and that crop irrigation seems more prevalent in the more arid climates.

TABLE 59
COMPARISON OF FULL YEAR OPERATIONS FOR BOTH ON-SITE AND MAIL SURVEYS

Climatic Zone	On-Site Survey Percent Operating 12 Months Communities	On-Site Survey Percent Operating 12 Months Industries	Mail Survey Percent Operating 12 Months Communities	Mail Survey Percent Operating 12 Months Industries
A	76		63	100
B	61		63	100
C	44	50	80	50
D	63	57	100	38
E	100	27	46	26

TABLE 60
DISTRIBUTION OF LAND APPLICATION SYSTEMS, BY FLOW RANGE AND NUMBER OF MONTHS PER YEAR SYSTEMS IN OPERATION – ON-SITE SURVEY

Months/Year Systems Operated	Flow Range–MGD 0-0.5		0.6-1.0		1.1-1.5		1.6-2.5		2.6-5.0		5.1-10.0		Over 100		No Data		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
									Communities									
1																		
2																		
3																		
4	1	1.5							1	1.5							2	3.0
5																		
6							1	1.5	1	1.5	1	1.5					3	4.5
7	3	4.5	1	1.5			2	3.0							2	3.0	8	12.0
8									1	1.5							1	1.5
9	1	1.5	1	1.5											1	1.5	3	4.5
10											1	1.5					1	1.5
11							1	1.5									1	1.5
12	6	8.9	11	16.4	6	8.9	7	10.4	9	13.4	1	1.5	2	3.0	2	3.0	44	65.5
No Data									1	1.5	1	1.5			2	3.0	4	6.0
Total	11	16.4	13	19.4	6	8.9	11	16.4	13	19.4	4	6.0	2	3.0	7	10.5	67	
									Industries									
1																		
2			1	5													1	5
3	1	5			1	5											2	10
4					1	5											1	5
5	1	5	1	5													2	10
6			1	5													1	5
7	1	5			1	5											2	10
8																		
9	1	5			1	5											2	10
10																		
11			1	5													1	5
12	3	15	3	15					2	10							8	40
No Data																		
Total	7	35	7	35	4	20			2	10							20	

TABLE 61
DAYS PER WEEK LAND APPLICATION SYSTEMS OPERATED BY CLIMATIC ZONE
ON-SITE SURVEY

No. Days/Wk. System Operated	Climatic Zone A No.	A %	B No.	B %	C No.	C %	D No.	D %	E No.	E %	Total No.	Total %
					Communities							
1	2	3.0					1	1.5			3	4.5
2											–	
3											–	
4							1	1.5			1	1.5
5	2	3.0									2	3.0
6					1	1.5					1	1.5
7	17	25.3	8	11.9	6	8.9	2	3.0	1	1.5	34	50.6
Variable	2	3.0	3	4.5			2	3.0			7	10.5
No Data	2	3.0	12	17.9	2	3.0	2	3.0	1	1.5	19	28.4
Total	25	37.3	23	34.3	9	13.4	8	12.0	2	3.0	67	
					Industries							
1											–	
2											–	
3											–	
4											–	
5*					1	5	2	10	1	5	4	20
6									2	10	2	10
7					1	5	4	20	7	35	12	60
Variable							1	5	1	5	2	10
No Data												
Total					2	10	7	35	11	55	20	

The other community and industrial systems covered in both surveys operate from two to eleven months of the year. No apparent relationship was found between wastewater flow and the number of months the systems are operated, as indicated in Table 60, Distribution of Land Application Systems by Flow Range and Number of Months per Year Systems in Operation – On-Site Survey.

Approximately 51 percent of the community and 60 percent of the industrial systems operate seven days a week, as depicted in Table 61, Days per Week Land Application Systems Operated by Climatic Zone – On-Site Survey. Three community systems reported operation on only one day a week. The predominance of five, six or seven-day operations tends to reflect normal personnel policies and hours of operation among the respective communities and industries. A supplemental comparison of weekly operations is presented in Table 62, Weekly Operations for Community and Industrial Systems by Climatic Zone – Mail Survey. For all of the 122 community and industrial systems reporting specific days-of-week operations, 27 percent function less than a full week and 29 percent operate for the full seven days. The tabulation in Table 62 indicates that many installations of community and industry nature provided no data on number of days per week irrigation is practiced. These Table 62 findings vary somewhat from the on-site survey data, insofar as they indicate a greater percentage of partial-week operations. No clear-cut pattern exists concerning the relationship of climate and days of operation. The data can be interpreted to show that no major differences in full-week and partial-week operations exist from one climatic region to another.

A compilation of mail survey data to establish the relationship of weekly operations and disposal field soil characteristics is presented in Table 63, Comparison of Days of Operation per Week to Soil Types – Mail Survey. These data indicate that partial-week operations occur more often with gravel soils. Overall, the relationship between weekly operations and soil types appears relatively inconclusive.

Table 64, Distribution of Land Application Systems by Flow Range and Number of Days per Week Systems in Operation – On-Site Survey, shows that most of the community and industrial systems that reported less than full-week operation serve average flows of one mgd or less.

TABLE 62
WEEKLY OPERATIONS FOR COMMUNITY AND INDUSTRIAL SYSTEMS BY CLIMATIC ZONE – MAIL SURVEY

No. of Days Irrigated Per Wk.	Climatic Zones; Cumulative Number and Percent											
	A		B		C		D		E		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-2	7	14	3	15			1	6	1	3	12	10
0-4	8	16	3	15			3	19	3	10	17	14
0-6	13	26	7	35	1	14	4	25	8	27	33	27
7	9	18	4	20	3	43	8	50	10	33	34	28
No Data	12		3		3	43			8		26	21
Total	49		20		7		16		30		122	

TABLE 63
COMPARISON OF DAYS OF OPERATION PER WEEK TO SOIL TYPE[1] MAIL SURVEY

Days Irrigated Per Wk.	Soil Type						Total	
	Loam	Silt	Clay	Sand	Gravel	Other	No.	%
0-2	3	1	4	6	3		17	10.7
0-4	4	1	6	9	4		24	15.2
0-6	13	3	8	13	7		44	27.8
7	16	9	13	15	5	1	59	37.3
No Data	16	2	10	18	9		55	34.8
Total	52	16	41	61	28	1	199	

[1] Many facilities indicated more than one soil type

TABLE 64
COMPARISON OF DAYS OPERATED PER WEEK TO GROUND COVER – MAIL SURVEY

Days Irrigated Per Wk.	No Veg.	No Cult.	Grass	Forest	Crops	No Data	Total
0-2		3	4		4		11
0-4		4	7	1	6		18
0-6	1	6	18	3	11		39
7	4	1	21	2	5		33
No Data	6	9	17	2	2	14	50
Total	11	16	56	7	18	14	122

Wastewater Application The methods employed in applying wastewaters to the land – spray irrigation, overland flow, and ridge and furrow irrigation – have already been evaluated in other parts of this section, but the question of application will be covered in the following discussion, within the limits of available data.

The relationship of wastewater application rates and soils types appeared in Table 49, Classification by Soil Type and Wastewater Application Rates – On-Site Survey. These data indicate that no significant relationship beteween soils types and application rates appears to exist. This observation differs from what might be surmised in terms of the variable percolation rates and soil permeabilities associated with the soil types investigated. On this basis it appears that application rates are affected by other factors than soils and perhaps ground cover types.

A summary of application rates is presented in Table 65, Summary of Application Rates – On-Site Survey. The typical application rates for communities and industries are in the range of from 0.1 to 0.5 inches per day.

Table 66, Groundwater Problems and Rate of Wastewater Application – On-Site Survey, depicts the relationship of groundwater interference with wastewater application rates. Over 13 percent of the communities, and 15 percent of the industries reported groundwater problems. No apparent significance can be derived from the relationship of groundwater interference and application rates. The question of groundwater interference was previously discussed in connection with application field characteristics. The mail survey data show that only 6 of 122 community and industrial systems reported use of underdrains. Each of these systems evidently employed underdrains to relieve groundwater problems.

TABLE 65
SUMMARY OF APPLICATION RATES FOUND — ON-SITE SURVEY

Wastewater Application	Community Systems		Industrial Systems	
Rates–in./day	No.	%	No.	%
0-0.10	9	13.4	1	5.0
>0.10-0.25	12	17.9	9	45.0
>0.25-0.50	15	22.4	7	35.0
>0.50-1.00	5	7.5	1	5.0
>1.00	7	10.5	2	10.0
No Data	19	28.4		
Total	67		20	100.0

TABLE 66
GROUNDWATER PROBLEMS

Wastewater Application Rates–in./day	Communities (67)					
	Yes		No		No Data[1]	
	No.	%	No.	%	No.	%
<0.10			9	13.4		
0.11-0.25	3	4.5	9	13.4		
0.26-0.50	3	4.5	10	14.9	2	3.0
0.51-1.0			5	7.5		
>1.0	2	3.0	3	4.5	2	3.0
No Data	1	1.5	16	23.9	2	3.0
Total	9	13.4	52	77.6	6	9.0
			Industries (20)			
<0.10	1	5.0				
0.10-0.25	2	10.0	6	30.0	1	5.0
0.26-0.50	1	5.0	6	30.0		
0.51-1.0	1	5.0				
>1.0	1	5.0	1	5.0		
No Data						
Total	6	30.0	13	65.0	1	5.0

[1] No data re groundwater problems

[2] No data re application rate

Handling of Excess Wastewater Over two-thirds of the communities did not report on the handling of surface runoff of excess wastewater, generally because at the low application rates, such flow does not occur. Table 67, Disposal of Excess Wastewater from Land Application Systems – On-Site Survey, shows that 11 community systems and 2 industrial systems discharged their surplus wastewaters to surface waters. The remaining systems reapplied their excess wastewaters to the application site. The methods employed to collect and transport excess wastewaters are not disclosed in the data from the on-site survey. The only supplementary data available from the mail survey relate to the use of underdrain systems which have been previously discussed.

Other Auxiliary Uses of the Land Application Site Another aspect of system operations involves uses of the land application site, other than for the application of wastewaters. These may be primary uses supplemented by wastewater irrigation, or subsidiary uses that exist because of wastewater irrigation. Table 68, Use of Land Application Areas – On-Site Survey, shows that 55 percent of the communities reported use of wastewater disposal sites for farming and 45 percent indicated use for grazing. One industrial site reported auxiliary land use for grazing and another for farming. Although 22 percent of the communities reported uses other than farming and grazing, only a few communities indicated the nature of this "other" use. Watering of golf courses is one of the predominant "other" uses.

Land Application Site Security The function of site security is to protect the wastewater land application site from the public and also to protect the public from the site, where warranted. Approximately 55 percent of the community and 50 percent of the industrial land application sites are fenced. Table 69, Security Arrangements at Land Application Sites – On-Site Survey, shows that 55 and 50 percent of the community and industrial systems, respectively, are accessible to the public. The 46 percent of the community systems with residences on the application site corresponds to the 45 to 55 percent of the community installations used for grazing or farming.

TABLE 67
DISPOSAL OF EXCESS WASTEWATER FROM LAND APPLICATION SYSTEM – ON-SITE SURVEY

	Number of Survey Reports					
	Yes		No		No Information	
Disposal of Excess Wastewater	No.	%	No.	%	No.	%
			Communities (67)			
Effluent used for other purposes			12	17.9	55	82.1
Reapplied to disposal area	3	4.5	13	19.4	51	76.1
Discharged to surface waters	11	14.9	11	14.9	45	67.2
			Industries (20)			
Effluent used for other purposes			17	85	3	15
Reapplied to disposal area	2	10	15	75	3	15
Discharged to surface waters	2	10	12	60	6	30

TABLE 68
USE OF LAND APPLICATION AREAS – ON-SITE SURVEY

	Yes		No		No Information	
	No.	%	No.	%	No.	%
Land Use			Communities (67)			
Farming	35	55.2	14	20.9	16	23.9
Grazing	30	44.8	16	23.9	21	31.3
Other	15	22.4	2	3.0	50	74.6
			Industries (20)			
Farming	1	5	15	75	4	20
Grazing	1	5	16	80	3	15
Other			1	5	19	95

TABLE 69
SECURITY ARRANGEMENTS AT LAND APPLICATION SITES–ON-SITE SURVEY

Security Arrangements	Number of Survey Reports					
	Yes		No		No Information	
	No.	%	No.	%	No.	%
Communities (67)						
Fenced	37	55.2	26	38.8	4	6.0
Patrolled	11	16.4	52	77.6	4	6.0
Posted	23	34.3	40	59.7	4	6.0
Residences on Premises	31	46.3	30	44.8	6	8.9
Accessible to Public	26	38.8	37	55.2	4	6.0
Other			62	92.5	5	7.5
Industries (20)						
Fenced	10	50	9	45	1	5
Patrolled	2	10	17	85	1	5
Posted	3	15	16	80	1	5
Residences on Premises	2	10	17	85	1	5
Accessible to Public	12	60	7	35	1	5
Other			19	95	1	5

Discussion The data from both the on-site and mail surveys are in general agreement on annual operating continuity. The majority of community systems maintain year-round operations, while industrial systems do not. As pointed out in previous discussion of this facet of application site management, many of the industries investigated were canning plants with seasonal operations. Partial-year system operations range from two to eleven months.

In terms of weekly operations, approximately half of the systems operate on a full-week basis and half do not. The question of weekly operations was investigated in terms of soil types, ground covers, and wastewater flow The results of these investigations must be termed inconclusive, because the choice between 5 or 6 and 7 days of operation may be greatly influenced by local personnel policies and practice. Investigation of weekly application operations and average flows, however, showed that those systems indicating less than full-week irrigation generally had flows of one mgd or less.

Nearly two-thirds of industrial application sites are accessible to the public; among communities, 39 percent allow public access. On the other hand, 55 percent of the community sites are fenced and half of the industrial sites provide fencing.

Systems and Environmental Monitoring and Performance

Monitoring Environmental and systems monitoring involves wastewater analysis for specific quality parameters and the analysis of the various flora and fauna that can be affected by land application processes. Biochemical oxygen demand, suspended solids and pH are the parameters most commonly determined for both the wastewater being transported to the land application site and the groundwater discharge from the site. Table 70, Communities – Analysis of Wastewater to Application Site and Effluent or Groundwater-Discharge from Site by Climatic Zone and Parameter – On-Site Survey, indicates the sampling and testing parameters employed under current practice at those application sites which maintain testing programs. The number of *yes* responses is based on the number of systems located in each climatic zone rather than the total number of systems investigated. Analyses are generally performed on the wastewater effluents of treatment plants which are transported to the application site. Few tests, however, are performed on application system effluents or groundwater discharges. Wastewater and groundwater monitoring occurs more extensively in Zones A and B than in the other zones.

TABLE 70

COMMUNITIES–ANALYSIS OF WASTEWATER TO APPLICATION SITE AND EFFLUENT OR GROUNDWATER DISCHARGE FROM SITE BY CLIMATIC ZONE AND PARAMETER – ON-SITE SURVEY

	Climatic Zone											
Waste	**A**		**B**		**C**		**D**		**E**		**Total**	
Parameter	**No.**	**%[1]**	**No.**	**%[1]**	**No.**	**%[1]**	**No.**	**%[1]**	**No.**	**%[1]**	**No.**	**%[1]**
No. in Region	25		23		9		8		2		67	
					Wastewater to Land Application							
BOD	21	84.0	18	78.3	6	66.7	3	37.5	2	100.0	50	74.5
Suspended Solids	19	76.0	13	56.6	4	4.4	1	12.5	1	50.0	38	57.8
COD	5	20.0	8	34.7	1	11.1	2	25.0			16	23.9
pH	17	68.0	14	60.8	4	44.4	4	50.0	2	100.0	41	61.2
Fecal Coliform	5	20.0	6	26.1	2	22.2	1	12.5	1	50.0	15	22.4
Phosphorous	8	32.0	5	21.7	3	33.3	2	25.0			18	26.9
Total Nitrogen	10	40.0	6	26.1	2	22.2	1	12.5			19	28.4
Nitrate	8	32.0	7	30.4			1	12.5			16	23.9
Nitrite	6	24.0	7	30.4			1	12.5			14	20.9
Chloride	11	44.0	6	26.1	3	33.3	1	12.5			21	34.4
					Effluent or Groundwater Discharge							
BOD	16	64.0	5	21.7	1	11.1	2	25.0	1	50.0	25	37.3
Suspended Solids	15	60.0	4	17.4	1	11.1	1	12.5	1	50.0	22	35.9
COD	6	24.0	2	8.7			1	12.5			9	13.5
pH	12	48.0	6	26.1	2	22.2	2	25.0			22	35.9
Fecal Coliform	2	8.0	3	13.0	1	11.1	1	12.5			7	10.5
Phosphorous	6	24.0	1	4.3	1	11.1	1	12.5			9	13.5
Total Nitrogen	4	16.0			1	11.1	1	12.5			6	9.0
Nitrate	11	44.0	2	8.7			1	12.5			14	20.9
Nitrite	3	12.0	2	8.7			1	12.5			6	9.0
Chloride	9	36.0	1	4.3	1	11.1	1	12.5			12	17.9

[1] Percent is based on "yes" responses for the region

The wastewater and groundwater monitoring practices for the industrial systems are portrayed in Table 71, Industry – Analysis of Wastewater to Application Site and Parameter – On-Site Survey. The comparison of community and industrial monitoring programs shows minor differences for the same regions. The number of parameters investigated for the industrial wastewaters of Zone D and for the community wastewaters of Zone E were limited. Industrial systems reported somewhat more effluent or groundwater discharge monitoring. This increased industrial site monitoring places greater emphasis on suspended solids, chemical oxygen demand and chlorides than do the corresponding community systems. It was found, however, that one or two community and industrial systems in each of Zones C, D and E account for the analysis of the additional parameters other than biochemical oxygen demand, suspended solids, chemical oxygen demand and pH.

Table 72, Environmental Monitoring at Land Application Areas – On-Site Survey, indicates that little difference exists between community and industrial systems in percentages of installations which use test wells and monitor the soil, groundwater, vegetation and other environmental factors.

A review of 122 community and industrial land application systems covered by the mail survey discloses that test wells occur in only 11 of these systems, or 9 percent. A recapitulation of the mail survey data on test wells appears in Table 73, Use of Test Wells at Land Application Sites – Mail Survey.

TABLE 71
INDUSTRY–ANALYSIS OF WASTEWATER TO APPLICATION SITE PARAMETER – ON-SITE SURVEY

	Climatic Zone							
Waste	C		D		E		Total	
Parameter	No.	%	No.	%	No.	%	No.	%[1]
No. in Region	2		7		10		20	
			Wastewater to Land Application					
BOD	1	50.0	5	71.4	4	36.0	10	50.0
Suspended Solids	1	50.0	4	57.3	4	36.0	9	45.0
COD	1	50.0			2	18.0	3	15.0
pH	1	50.0	5	71.4	3	27.0	9	45.0
Fecal Coliform	1	50.0			1	9.0	2	10.0
Phosphorous	1	50.0			3	27.0	4	20.0
Total Nitrogen	1	50.0			3	27.0	4	20.0
Nitrate					1	9.0	1	5.0
Chloride	1	50.0			1	9.0	2	10.0
			Effluent or Groundwater Discharge					
BOD	1	50.0	3	43.0	5	45.0	9	45.0
Suspended Solids	1	50.0	5	71.4	5	45.0	11	55.0
COD	1	50.0	2	28.6	4	36.0	7	35.0
pH	1	50.0	4	57.3	5	45.0	10	50.0
Fecal Coliform	1	50.0	2	28.6	1	9.0	4	20.0
Phosphorous	1	50.0	2	28.6	1	9.0	4	20.0
Total Nitrogen	1	50.0	2	28.6	2	18.0	5	25.0
Nitrate	1	50.0	2	28.6	2	18.0	5	25.0
Nitrite	1	50.0	2	28.6			3	15.0
Chloride	1	50.0	3	43.0	1	9.0	5	25.0

[1] Percent based on "yes" responses for region

TABLE 72
ENVIRONMENTAL MONITORING AT LAND APPLICATION AREAS – ON-SITE SURVEY

	Number of Survey Reports					
Type of Monitoring	Yes No.	Yes %	No No.	No %	No Information No.	No Information %
			Communities (67)			
Test Well	18	23.9	31	46.4	18	26.9
Influent	27	40.3	20	29.8	20	29.8
Effluent	31	46.4	22	32.8	14	21.9
Soil	6	9.0	28	41.8	33	49.4
Groundwater	14	20.9	24	35.8	29	43.4
Vegetation	7	10.5	27	40.3	33	49.4
Animal and Insect	9	13.5	27	40.3	31	46.4
Other	4	6.0	22	31.8	41	61.3
			Industries (20)			
Test Well	5	25	11	55	4	20
Influent	9	45	9	45	2	10
Effluent	8	40	7	35	5	25
Soil	4	20	11	55	5	25
Groundwater	4	20	12	60	4	20
Vegetation	2	10	13	65	5	25
Animal and Insect	1	5	15	75	4	20
Other	1	5	12	60	7	35

Other than influent and effluent monitoring, 22 percent of the community systems and 20 percent of the industry systems monitor groundwater. Soils analyses are carried out at 20 percent of the industrial systems. Table 74, Land Application Area Monitoring by Climatic Zone – On-Site Survey, shows some regional differences, as well as community and industry differences. The limited number of positive responses, however, indicates that environmental monitoring is generally not practiced at land application sites. Where monitoring is being performed, adverse impacts have not been noted.

All phases of site are influenced by the policies and practices of state and local local health agencies and water pollution control agencies in the regulation of wastewater land application stems. The interest of these agencies on one hand, can reflect their concern for some of the potential problems that can develop among improperly operated systems – public health hazards, pollutional problems, nuisance effects, etc. The involvement of these agencies would indicate an effort to monitor and periodically inspect wastewater land application facilities. Table 75, Summary of Public Health Agency Involvement – On-Site Survey, indicates the number of community and industrial systems which reported that they were subject to state and local health restrictions. Of 67 community systems, approximately half indicated that they operate under public health restrictions and half did not. The industry systems reported that 80 percent operated without public health restrictions and only 15 percent reported such restrictions.

Discussion The existing programs of systems and environmental monitoring show wide variances in the types of quality and other parameters monitored and evaluated in influent wastewaters, effluent wastewaters, soils, and groundwaters. Biochemical oxygen deman, suspended solids and pH are the parameters most frequently investigated for influent and effluent wastewaters and groundwaters among the communities studied. Industrial systems monitoring practices stress suspended solids, chemical oxygen demand and chloride levels. In all cases, less than half oof the community and industrial systems make any consistent effort to maintain environmental and systems monitoring programs which reflect influent quality, soils, vegetation, animal and insect life, effluent quality, groundwater quality and any other impacts of the land application process.

TABLE 73
USE OF TEST WELLS AMONG LAND APPLICATION SITES – MAIL SURVEY

	Number of Systems	Percentage
Test Wells Exist	11	9.0
Test Wells Don't Exist	16	13.1
No Data	95	77.9
Total	122	

Performance of Existing Systems

The performance of land application systems can be determined in a variety of ways. Satisfaction on the part of the operating agencies provides one such measure. Perhaps the most telling demonstration of current experience with land application systems is the intention of owners of existing installations to continue or enlarge them. Seventy five percent of industries plan to continue use of their present land application facilities. A summary of plans for existing application systems appears in Table 76, Plans for Land Application Systems by Climatic

TABLE 74
LAND APPLICATION AREA MONITORING BY CLIMATIC ZONE – ON-SITE SURVEY

Type of Monitoring	Number and Percent of "Yes" Replies by Climatic Zone											
	A		B		C		D		E		Total	
	No.	%[1]	No.	%[1]	No.	%[1]	No.	%[1]	No.	%[1]	No.	%
						Communities						
No. of Communities	25	–	23	–	9	–	8	–	2	–	67	–
Test Wells	8	32.0	1	4.4	5	55.6	3	37.5	1	50.0	18	23.9
Influent	20	80.0	3	13.0	2	22.2	2	25.0			27	40.3
Effluent	19	76.0	4	17.4	5	55.6	3	37.5			31	46.4
Soil			2	8.7	3	33.3	1	12.5			6	9.0
Groundwater	8	32.0			4	44.4	2	25.0			14	21.9
Vegetation	3	12.0	1	4.4	2	22.2	1	12.5			7	10.5
Animal and Insects	7	28.0	1	4.4			1	12.5			9	13.5
Other	1	4.0	1	4.4			2	25.0			4	6.0
						Industries						
No. of Industries					2	–	7	–	11	–	20	
Test Wells							2	28.6	3	27.0	5	25.0
Influent					2	100.0	4	57.3	3	27.0	9	45.0
Effluent					2	100.0	3	43.0	3	27.0	8	40.0
Soil					1	50.0	1	14.3	3	27.0	4	20.0
Groundwater					1	50.0	1	14.3	2	18.0	4	20.0
Vegetation					1	50.0			1	9.0	2	10.0
Animal and Insect									1	9.0	1	5.0
Other							1	14.3			1	5.0

[1] Percent is based on number of survey reports in the region

TABLE 75
SUMMARY OF PUBLIC HEALTH AGENCY INVOLVEMENT – ON-SITE SURVEY

	Communities		Industries	
	No.	%	No.	%
Yes	38	56.7	3	15.0
No	21	31.3	16	80.0
No Data	8	12.0	1	5.0
Total	67		20	

Zone – On-Site Survey. It shows that approximately 46 percent of the communities and 20 percent of the industries plan to expand their systems. The fact that the owners of over 90 percent of the community and 95 percent of industry land application systems plan to continue or expand their installations, indicates that the process and its performance are considered to be a satisfactory solution for wastewater management problems. Twenty-seven percent of the communities covered by the mail survey plan to continue the use of land application and approximately 47 percent plan to increase their operations. Among the industries, 61 percent plan to continue, but only 19 percent plan expansion. Only 3.3 percent of all the systems studied report that their land application operations will be reduced or abandoned. The mail survey confirms that a strong measure of satisfaction with the performance of land application has developed among the owners of the systems investigated. These data are presented in Table 77, Future Plans for Existing Land Application Systems – Mail Survey.

The proximity of residential and other land uses to the effluent application sites also provides another measure of system performance. The relatively close proximity of other land uses to continuing site operations indirectly suggests that these systems have no or minimal environmental and nuisance effects on the local areas. Table 78, Distance from Land Application Site to Nearest Residence by Climatic Zone – On-Site Survey, shows the proximity of application site to residential uses. Forty-nine percent of the community and 35 percent of the industrial systems reported that the nearest residence is located within 500 feet of their sites. An additional 27 percent of the communities and 35 percent of the industries reported that the nearest residence is between 500 and 1500 feet from sites. The fact that residences are located within 0.3 miles of community and industry land application systems concurs with the residential or farm zoning of contiguous areas. Despite this close proximity, 32 percent of industries which reported on this phase of land application reported no odor complaints.

TABLE 76
PLANS FOR LAND APPLICATION SYSTEMS BY CLIMATIC ZONE – ON-SITE SURVEY

Plans For Existing Systems	Climatic Zone A No.	A %[1]	B No.	B %[1]	C No.	C %[1]	D No.	D %[1]	E No.	E %[1]	Total No.	Total %
						Communities						
No. of Communities	25	–	23	–	9	–	8	–	2	–	67	–
Expand	12	48.0	13	56.6	3	33.3	3	37.5			31	46.3
Continue	11	44.0	9	39.1	5	55.6	4	50.0	1	50.0	30	44.7
Abandon	1	4.0									1	1.5
No Plans							1	12.5			1	1.5
No Data	1	4.0	1	4.3	1	11.1			1	50.0	4	5.0
Total	25		23		9		8		2		67	
						Industries						
No. of Industries					2	–	7	–	11	–	20	
Expand									4	36.4	4	20.0
Continue					2	100	6	85.7	7	63.6	15	75.0
No Data							1	14.3			1	5.0
Total					2		7			55.0	20	

[1] Percentages are of number of facilities in climatic zone

TABLE 77
FUTURE PLANS FOR EXISTING LAND APPLICATION SYSTEMS – MAIL SURVEY

Future Plans	Communities		Industries		Totals	
	No.	%	No.	%	No.	%
Expand	40	46.5	7	19.4	47	38.5
Continue	23	26.7	22	61.1	45	36.9
Decrease	1	1.2			1	0.8
Abandon	3	3.5			3	2.5
No plans	1	1.2	1	2.8	2	1.6
No data	18	20.9	6	16.7	24	19.7
Total	86		36		122	

TABLE 78
DISTANCE FROM LAND APPLICATION SITE TO NEAREST RESIDENCE BY CLIMATIC ZONE – ON-SITE SURVEY

Distance to Residence (ft)	A		B		C		Climatic Zone D		E		Total	
	No.	%[1]	No.	%	No.	%	No.	%	No.	%	No.	%
					Communities (67)							
Less than 500	13	52.0	14	60.9	3	33.4	2	25.0	1	50.0	33	49.2
500-1,500	6	24.0	4	17.4	2	22.2	3	37.5			15	27.3
1,500-5,000	3	12.0	3	13.0	2	22.2	1	12.5			9	13.5
Over 5,000	1	4.0			1	11.1	1	12.5			3	4.5
No Data	2	8.0	2	8.7	1	11.1	1	12.5	1	50.0	7	10.5
Total	25		23		9		8		2		67	
					Industries (20)							
Less than 500					2	10.0	1	14.3	4	36.4	7	35.0
500-1,500							5	71.4	2	18.2	7	35.0
1,500-5,000							1	14.3			1	5.0
Over 5,000									3	27.2	3	15.0
No Data									2	18.2	2	10.0
Total					2	10.0	7		11		20	

[1] Percentages are of facilities surveyed by climatic zone

Systems Zoning, Land Values, Capital Investment, Operating and Maintenance Costs

Zoning Farming represents the most common zoning land-use for community and industrial land applicaton sites and adjacent areas. Regional summaries of the zoning of community land application sites and adjacent areas appear in Table 79, Zoning of Community Land Application Facilities and Adjacent Areas by Climatic Zone – On-Site Survey. Zone D shows the only regional zoning difference, with 5 of 9 land application sites and adjacent areas zoned for residential use. The corresponding summary of industrial system zoning, Table 80, Zoning of Industrial Land Application Facilities and Adjacent Areas by Climatic Zone – On-Site Survey, shows that farm zoning applies to most industrial application sites and adjacent areas.

Land Values Land value involves the dollar values placed upon the properties used for land application. Table 81, Comparison of Application Site Land Value to Population – Mail Survey, presents the available data for 86 community and 36 industrial systems, listed in terms of population and application site land value. Generally, 57 percent of the community systems and 25 percent of the industrial systems studied did not report land values. Among the communities, 16 percent reported land values of $500 per acre or less; this amounts to 38 percent of the reports which quoted land value; 24 percent reported values at $1,000 per acre or less; this represents 57 percent of the reports which quoted land value. In similar manner, the industrial systems in 22 percent of the systems studied – 30 percent of the reports which quoted land values – are located on property valued at $500 per acre or less, and 59 percent of the total systems studies – 78 percent of the reports providing land value data – are located on property valued at $1,000 per acre or less. While some systems use land valued in excess of $2,000 per acre, these occur infrequently. From the foregoing, it appears that land application systems have usually been located on low-value land.

The on-site survey shows that the value of application site land does not vary from the value of adjacent property in most cases. A tabulation of this information appears as Table 82, Value of Land Application Site and Adjacent Property – On-Site Survey. A further summary of these data is presented in Table 83, Summary of Adjacent Land Values Compared to Application Site Land Values – On-Site Survey.

Three community and industrial systems reported a higher value per acre for the land application site than for contiguous lands, and three community and industrial systems reported a higher value for adjacent property.

Operation and Maintenance Expense Operating and Maintenance expense data for 30 of 67 community and 10 of 19 industrial systems appear in Table 84, Operating and Maintenance Expense by Climatic Zone – On-Site Survey. Twenty-one of the communities and 9 of the industries reported operation and maintenance expenses of less than $50,000 per year. Unfortunately, the data are too limited to warrant their interpretation to operating periods in days or months or to wastewater flows. It was apparent that land application costs are often included within the expense structure for the entire wastewater treatment operation. No additional supplementary data were deducible from the mail survey on land application operations and maintenance expense.

Discussion Land application facilities are located most frequently in relatively undeveloped areas, although some commercial and residential areas have been used. Generally, the land values associated with these facilities reflect this fact; a large percent of the systems reported land values of $500 per acre or less. The assumption that land application systems are located on marginal lands that have low value for other uses is confirmed by the fact that, in most cases, the value of adjacent properties does not differ significantly from that of the land used for application sites. Relative isolation and availability of necessary acreage appear to be the motivating factors in land application site selection. The initial selection of the waste treatment plant sites may have been induced by the same reason. Most land application facilities are located near the treatment plant.

Capital investment costs for land application could not be distinguished from

TABLE 79
ZONING OF COMMUNITY LAND APPLICATION FACILITIES[1] AND ADJACENT AREA BY CLIMATIC ZONE – ON-SITE SURVEY

Zoning Classification	Climatic Zone A	B	C	D	E	Total No.	Total %
		Land Application Facilities					
Residential	2	3	3	5		13	16.4
Industrial	6	1		1		8	10.1
Farm	14	15	5	2	1	37	46.9
Green Belt	1					1	1.3
Other	3	7	1		1	11	13.9
No Data	1	7				9	11.4
Total	27	33	9	8	2	79	
		Adjacent Area					
Residential	2	6	1	5		14	17.7
Commercial	2	2				4	5.1
Industrial	1	4	1	1		7	8.9
Farm	17	14	3	2		36	45.5
Green Belt		1				1	1.3
Other	1	3	3		1	8	10.1
No Data	4	3	1		1	9	11.4
Total	27	33	9	8	2	79	

[1] Some facilities reported more than one zoning classification

TABLE 80
ZONING OF INDUSTRIAL LAND APPLICATION FACILITIES[1] AND ADJACENT AREAS BY CLIMATIC ZONE ON-SITE SURVEY

Zoning Classification	Climatic Zone C	D	E	Total No.	Total %
	Land Application Facilities				
Industrial	1	1	1	3	12.5
Farm		4	10	14	58.3
Other		1	2	3	12.5
No Data	1	2	1	4	16.7
Total	2	8	14	24	
	Adjacent Areas				
Residential	1			1	4.2
Commercial		1		1	4.2
Farm			11	11	45.8
Green Belt		5		5	20.8
Other		1	2	3	12.5
No Data	1	1	1	3	12.5
Total	2	8	14	24	

[1] Some industries reported more than one zoning classification

TABLE 81
COMPARISON OF APPLICATION SITE LAND VALUE TO POPULATION – MAIL SURVEY

	Community Population (x 1,000)													
	0-5		>5-10		>10-25		>25-50		>100		No Data		Total	
Land Value $/Acre	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
0-500	11	12.8	2	2.3	1	1.2							14	16.3
500-1,000	2	2.3	2	2.3	3	3.5							7	8.1
1,000-2,000	3	3.5			1	1.2							4	4.6
>2,000	5	5.8	5	5.8					1	1.2			12	14.0
No Data	33	38.3	6	7.0	5	5.8	2	2.3	1	1.2			49	57.0
Total	54	62.8	15	17.5	10	11.6	2	2.3	2	2.4	3	3.5	86	
	Industrial Population Equivalents (x 1,000)													
0-500	2	5.6	1	2.8	2	5.6	1	2.8			2	5.6	8	22.2
500-1,000	4	11.1	1	2.8	5	13.9	1	2.8			2	5.6	13	36.2
1,000-2,000	1	2.8	1	2.8							1	2.8	3	8.3
>2,000	2	5.6			1	2.8							3	8.3
No Data	1	2.8	1	2.8	1	2.8					6	11.7	9	25.0
Total	10	27.8	4	11.1	9	25.0	2	5.6			11	30.5	36	

TABLE 82
VALUE OF LAND APPLICATION SITE AND ADJACENT PROPERTY – ON-SITE SURVEY

	Adjacent Property $/Acre											
Land Disposal Site $/Acre	Less than 500		500-1,000		1,000-2,000		Over 2,000		No Data		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
					Communities							
Less than 500	9	13.4									9	13.4
500-1,000	2	3.0	11	16.4	2	3.0			1	1.5	16	23.9
1,000-2,000					5	7.5					5	7.5
Over 2,000							11	16.4	2	3.0	13	19.4
No Data					1	1.5	4	6.0	19	28.3	24	35.8
Total	11	16.4	11	16.4	8	12.0	15	22.4	22	32.8	67	
					Industries							
Less than 500	7	35	1	5							8	40
500-1,000	1	5	8	40	1	5					9	45
1,000-2,000											1	5
No Data									2	10	2	10
Total	8	40	9	45	1	5			2	10	20	

TABLE 83
SUMMARY OF ADJACENT LAND VALUES COMPARED TO APPLICATION SITE LAND VALUES – ON-SITE SURVEY

Value of Application Site/Adjacent Area $/Acre	Percent Reporting Equal Land Values	
	Communities	Industries
Less than 500/ less than 500	82	88
500 - 1,000/ 500 - 1,000	100	89
1,000 - 2,000/ 1,000 - 2,000	63	100
Over 2,000/ Over 2,000	73	–

(Percentage is based only on number of communities reporting land value in each category.)

TABLE 84
OPERATING AND MAINTENANCE EXPENSE BY CLIMATIC ZONE ON-SITE SURVEY

Operating and Maintenance Budget – $	A		B		C		D		E		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
					Communities							
Less than 25,000	1	1.5	7	10.4	2	3.0	3	4.5	2	3.0	15	14.4
25,000-50,000	3	4.5	1	1.5	2	3.0					6	8.7
51,000-75,000	1	1.5	1	1.5							2	2.8
76,000-100,000	2	3.0	1	1.5							3	4.3
101,000-250,000	2	3.0					1	1.5			3	4.3
Over 250,000	1	1.5									1	1.4
No Data	15	22.4	13	19.4	5	7.4	4	5.9			37	63.7
Total	25		23		9		8		2		67	
					Industries							
Less than 25,000												
25,000-50,000							2	10.5	6	31.6	8	42.1
51,000-75,000							1	5.3			1	5.3
76,000-100,000									1	5.3	1	5.3
101,000-250,000												
Over 250,000												
No Data					2	10.5	4	21.1	4	18.4	10	50.0
Total					2		7		11		20	

total costs for treatment and other related facilities. In terms of operations and maintenance expenses, the majority of systems which reported indicated expenditures of less than $50,000 per year. Thus, in most cases, the costs of constructing and operating land applicaton facilities are relatively low in comparison with the costs of construction, equipment and operations for advanced treatemtn processes.

Miscellaneous System Benefits

The principal thrust of the foregoing evaluation of land application practices has dealt with the many factors that enter into the design, operation, monitoring and costs of such systems. Another area of interest concerning some of the previously unspecified benefits from wastewater application remains to be investigated.

The discussion of costs touched upon the question of land values. Importantly, the relative value of land application sites was found to be consistent with the value of adjacent properties. Thus, the land application site may represent an asset subject to appreciation or depreciation at an equal rate to surrounding property should it be feasible in the future to adopt another means of treatment.

The use of wastewater in irrigation provides another benefit or asset, in terms of the crops grown and their actual value. On one hand, wastewater irrigation provides some degree of crop or forest enhancement due to its nutrient value. An obvious degree of crop enhancement must derive from a consistently available source of irrigation water. Table 85, Wastewater Irrigated Crop Types – On-Site Survey, defines the types of crops irrigated with wastewater. Cereals were reported to be the major crop type, representing 47 percent of the total irrigated acreage available. Within the cereals group, corn is grown on 30 percent of the available acreage. Feeds are irrigated on 24 percent of the available acreage, and alfalfa alone represents 23 percent. Alfalfa occurs most frequently – planted on 19 of 93 separate application sites. Wastewater is also used to irrigate fruit, vegetables, fiber crops, grasses, pasturage and flowers. In addition, the use of irrigation in forested areas enhances lumber yields and also produces intangible benefits in terms of silvan aesthetics.

No dollar value figures can be deduced for specific crops or for any crop yields associated specifically with wastewater irrigation crop enhancement. Non-specific dollar values do exist for irrigation site usage. These appear in Table 86, Comparison of Annual Dollar Return to Irrigated Site Acreage – On-Site Survey. The 14 reporting systems indicated an annual return of up to $100 per acre or more. Almost 86 percent of the systems reporting realize a yield of $50 per acre or less, and less than 30 percent realize a yield of $5 per acre or less. Effective land management should be able to provide an annual site yield of $50 per acre or higher.

Recreational opportunities represents another important benefit of the use of wastewater irrigation. Table 87, Recreational Uses Associated with Land Application –On-Site Survey, indicate some of the current recreational uses of wastewater irrigation. Of a total of 67 communities, 66 percent obtain no recreational returns, while only one industry (5%) derived any such advantage. The major recreational use is for golf courses, wildlife refuges, and hunting and fishing. Golf course irrigation is practiced by 18 percent of the systems; and hunting and fishing occur only in 5 percent of the community systems reporting.

Discussion Miscellaneous returns or benefits are derived from land application. The benefits or assets include accrued or enhanced land values, crop production, silviculture and horticulture growths, and, finally, recreational uses. In terms of site land values, the representations of the discussion on system costs were reiterated to confirm the fact that site land values do not suffer as a result of land application. If anything, these land values will increase in the long term.

A wide variety of crops are irrigated with wastewater. The majority of these crops are cereals that are usually subject to some form of processing prior to consumption. Animal feeds represent the next most common type of wastewater-irrigated crop.

TABLE 85
WASTEWATER IRRIGATED CROP TYPES – ON-SITE SURVEY
(140,000 Acres)

Crop Type	Number of Sites Planted		Acres Grown		% of Total Irrigated Acreage	
	Total	Each	Total	Each	Total	Each
Animal Feeds	22		33,882		24.2	
Alfalfa		19		32,765		23.4
Hay		2		1,117		0.8
Fodder		1				
Cereals	38		66,170		47.3	
Corn		11		41,520		29.7
Barley		4		730		0.5
Maize		5		100		0.1
Millet		2				
Oats		5				
Sorghum		3		40		0
Wheat		7		23,780		17.0
Rye		1				
Fruits	4		92		0.0	
Apples		1				
Citrus		2		72		
Grapes		1		20		
Row Crops	4		5,500		3.9	
Tomatoes		1		3,700		2.6
Chili Peppers		1		1,850		1.3
Miscellaneous		2				
Fiber Crops	9		825		0.6	
Cotton		8		825		0.6
Kenaff		1				
Grasses	12		1,420		1.0	
Bahia		1				
Bermuda		4		425		0.3
Fescue		1		70		
Sudan		1				
Milo		5		925		0.7
Pasturage	2		1,000		0.7	
Flowers	1		240		0.2	
Miscellaneous	1		12,710		9.1	
Unspecified			18,167		13.0	
Totals	93		140,006		100	

TABLE 86
COMPARISON OF ANNUAL DOLLAR RETURN TO IRRIGATED SITE ACREAGE – ON-SITE SURVEY

Annual Yield in $/Acre	Acres Irrigated 10-50	50-200	200-1,000	>1,000	Total
0-5	1	1		2	4
5-10			1		1
10-25		1	2		3
25-50	1	1	1		3
50-100	1	1	1		3
>100			1	1	2
Total	3	4	6	3	16

TABLE 87
RECREATIONAL USE ASSOCIATED WITH LAND APPLICATION ON-SITE SURVEY

Recreational Use	Communities No.	%	Industries No.	%
Golf	12	17.9		
Hunting and/or Fishing	3	4.5	1	5.0
Park and Picnic Area	1	1.5		
Other				
No Data	7	10.4	1	5.0
None	44	65.7	18	90.0
Totals	67		20	

Annual dollar yields on irrigation sites from land rentals and crop returns in most of the systems approach a level of $50 per acre or less. The most common recreational uses associated with land application are golf and hunting and fishing. These represent intangible returns that defy definition in terms of associated money values.

Bibliographic Review

A large body of technical literature on various aspects of the land application of wastewater and sludge has been collected as a part of the study. A bibliography of the literature was prepared. An intensive search of all available sources covering this subject was made. Extensive use was made of bibliographies prepared by the Texas Water Quality Control Board, The California Department of Water Quality, and publications of USEPA.

The bibliographers found a great wealth of information in various forms and on various aspects of land application.

This broad and often bewildering array of technical-scientific data may be a liability, rather than an asset, for researchers who are seeking specific guidance on any definitive facet of the multi-disciplinary and multi-purpose subjects involved. The task, in such circumstance, is to screen and classify all available bibliographic material and to select from the mass those matters of moment which will add to the fund of knowledge pertinent to the subject of this research project.

The bibliographic search revealed the fact that wastewater application to land areas involves many disciplines, many physical factors, and numberous specialized scientific authorities. The subjects involved relate, specifically, to the process of applying moisture to soils and, non-specifically, to related and semi-related principles and practices. Over 430 items of literature were examined.

The interdisciplinary involvements in land application of wastewaters are impressive. The subjects represented a compendium of knowledge that covers the total spectrum of sciences which involve: Branches of engineering, chemistry, biochemistry, biology, bacteriology, virology, physics, climatology, agronomy, animal husbandry, limnology, minerology, public health, economics, geology, medicine, pathology, and other specilized fields.

Involved in the literature on this subject are such matters as those relating to the management of agricultural yields, methods of irrigation, meteorology, dairy herds, food processing, water supply sources and their protection, water pollution control, treatment of sewage and industrial wastes, and others. Each has a bearing on the feasibility, workability and applicability of the land application process.

Many other studies of land application of wastewaters have been carried out prior to the current research project reported in this document, and other investigations are now underway under the auspices of the U.S. Environmental Protection Agency or other entities. All researchers have found it necessary to prepare similar literature search data.

Therefore, it has been deemed advisable to prepare one single master bibliographic reference, entitled Land Application of Sewage Effluents and Sludges, Selected Abstracts, into which all of the investigating agencies can coordinate their individual reference searches. This report will be available from the USEPA in late 1973. The American Public Works Association is pleased to have had the opportunity to contribute its bibliographic efforts, as described above, to this composite effort. This consolidation of all current bibliographic work into one record will add to the value of this reference document and avoid the confusion and duplications which separate reference lists would cause.

SECTION IV
SURVEY OF OPINIONS AND REGULATIONS OF STATE HEALTH AND WATER POLLUTION CONTROL AGENCIES ON THE APPLICATION OF WASTEWATERS ON LAND AREAS

State regulatory agencies, traditionally, have maintained control over water resources which are utilized for public water supply purposes, body-contact recreation, the spawning and propagation of fish and shellfish, refuge for wildlife, industrial processing, and other multi-purpose uses. This has involved these state agencies in regulatory procedures affecting the use of water resources as the recipients of wastewaters from points of pollution and non-point pollution sources. While earlier regulatory practices were limited to surface water sources, broader and more comprehensive definitions of "public waters" are now in effect. Under this broader concept of what constitutes water resources, the quality of groundwaters has become a concern of the states.

More recent concern over the *total* environment has added further dimension to the sphere of control undertaken by both State Health Departments and Water Pollution Control Agencies. In this connection, the duality of land resources and water resources has been recognized and more rigid control over the use of land areas for the disposal of the wastes of man's life and living processes has been invoked. To add to this dual land-water concept, the inevitable relationship between land, water and air resources has come under state regulatory concern and surveillance. This concept of the linkage of water, land and air is based on the incontrovertible physical principle that what is done to affect or protect one resource will affect the usefulness and safety of the others to serve as safe environments for man and his functions.

If the alternative method of managing wastewater effluents by application on land areas is to become more universally utilized by municipalities and industries it must receive more specific consideration by state health and natural resources authoritites than it is now given. The fact that the one thousand and more land application sites now in service in the United States have received minimal regulatory control in the past emphasizes the need for a greater recognition of the problem and a consequent increase in regulatory control in the future.

In order to determine the extent of current regulatory practices and to ascertain those facets of the problem which are being stressed or disregarded, two inquiries were instituted: one addressed to State Health Departments, and the other to State Water Pollution Control Agencies. The findings are presented in the two tabulations which follow.

The survey by mail of the policies of health agencies definitively addressed itself to the question of the safety of wastewater effluents discharged onto land areas, in terms of disinfection and freedom from toxic contaminants and organisms of the coliform group, and to the disposition of forage, crops and silviculture growths produced on and/or harvested from these land areas.

The survey of opinions and policies of water pollution control agencies involved broader-based environmental matters; they related to actual guidelines for design, construction, operation and control of land application systems and the official requirements covering influent wastewater quality, and safety provisions.

State Health Policies

The survey of health agency policies must be characterized as merely symbolic of national practices since only 30 states responded to the fact-finding inquiry. Only five states indicated that official regulations governing irrigation with wastewaters are in effect: Arkansas, Arizona, Colorado, New Mexico and Texas. With land application now viewed as a possible alternative method of wastewater management, based on a rational interpretation of the 1972 Amendments to the Federal Water Pollution Control Act, other states may find it necessary to invoke statutory standards or rules and regulations to govern this method of effluent management.

Only four states, Arizona, Arkansas, New Mexico and Texas, indicated that they have rules governing the types of crops approved for wastewater irrigated lands. Such crops range from "forage only" to "all types." Texas regulations demonstrate concern over consumption of raw crops from wastes-contact areas. The state limits crops to those not consumed in the raw state.

The few states which invoke crop restrictions of any nature also specify the quality of effluent applied to the land.

In addition to the states which have established effluent quality criteria and crop-control procedures, other states expressed concern over wastewater applications which are not disinfected by adequate chlorination. They stated their concomitant disfavor for the consumption of crops grown on such lands. In specific cases, the attitude of health officials can be summed up as discouraging the harvesting of crops for human consumption.

Table 88, Survey of Wastewater Irrigation, State Public Health Regulations, lists replies by individual states. Also contained in this section are examples of regulatory documents issued by Arizona, Colorado, Florida, Texas and the "Ten States" of the Great Lakes-Upper Mississippi Basin, as Exhibits I through V.

State Water Pollution Control Agency Policies

The survey of policies of water pollution control agencies was slightly more productive, but the limited number of agencies which offered any specific evidences of official concern for land application systems revealed that they had not yet found the relevancy of this process because of the infrequency of use in some areas and their inability to consider the related problems with the limited staffs available in their agencies.

The following listing of commentaries on various matters covered by the survey questionnaire, received from approximately 27 state agencies, clearly indicates the lack of information upon which to base any cogent conclusions on state policies.

Phase of Land Application Practices	Number of Positive State Replies
Statutes and Codes/Design Criteria/Staff Standards	7
Effluent Pretreatment Requirements	7
Distinction between Sewage and Industrial Wastes	4
Control of Effluent Quality Applied to Land	4
Storage of Applied Effluent Required	3
Standby Acreage Required	2
Buffer Zones Required	2
Area Protection Required	3
Safety and Safeguard Requirements	4
Seasonal Variations Recognized	2
Design Guidelines	5

Table 89, State Water Pollution Control Agency Responses, lists replies by individual states. The survey requested comments on land application practices and potentials, in the hope that such views would indicate what policies and regulations might be expected in the future. The comments, though few in numbers, were somewhat revealing. Paraphrased, they can be expressed in the following words:

'No problem; the only requirements would be to protect water supplies'

'Consider land application as an experimental procedure'

'No objection if properly controlled'

'Can be used under specific conditions'

'Concerned with health and nuisance hazards'

'Not viewed as a suitable method of disposal for raw or treated wastes'

'Each proposal must be considered as a separate case, on its own merits'

'Several systems being considered'

TABLE 88
SURVEY OF WASTEWATER IRRIGATION–STATE PUBLIC HEALTH REGULATIONS

State	Regulations Governing Wastewater Irrigation	Wastewater Products Considered	Type of Crop Specified	Wastewater Quality Limits Specified	Comments
Alabama	None			None	
Alaska	None			None	
Arizona	Yes	Treated domestic effluent	All	Yes	
Arkansas	Yes	a. Treated domestic effluents b. Treated industrial sludges	Forage	None	Wastewater is generally discouraged and is approved only with close supervision
Colorado	Yes			Yes	Chlorination required
Connecticut	None				Would look with disfavor on use on crop. May be some possibilities for use on forest areas
District of Columbia	Not permitted			None	
Florida	None				Guidelines issued in 1972
Georgia	None				
Illinois	None				
Kentucky	None				
Maryland	None				
Massachusetts	None			None	
Mississippi	None				Should not be used on food crops, especially those eaten "raw"
Missouri	None				
Nebraska	None				
Nevada	None	Secondary effluent			Chlorination required unless lagoon storage for 100 days
New Hampshire	None				
New Mexico	Yes	+Related domestic and industrial effluent	All	Yes	Chlorination required
New York	None			None	
Pennslyvania	None				Require chlorination. Each installation must have a specific permit
South Carolina	None				
South Dakota	None				
Tennessee	None			None	

TABLE 88 – Continued

State	Regulations Governing Wastewater Irrigation	Wastewater Products Considered	Type of Crop Specified	Wastewater Quality Limits Specified	Comments
Texas	Yes	Treated domestic effluents	All crops except foods consumed raw	BOD-20 ppm–SS^5-30 ppm MPN 50/100 m Cl residual of 2-5 ppm for 20 min. Contact period immediately prior to application	Staff recommendations formulated by the Division of Wastewater Technology and Surveillance, Texas State Department of Health
Vermont					Do not encourage use. Can be placed on fields and corn crops if plowed under within 48 hours
Virginia	None				Individual permit required
Washington	None			None	
West Virginia	None				Evaluated on an individual basis
Wyoming	None				

'Mountainous terrain discourages use of this method of disposal'

'Encourage use of well-treated effluents for pastures, wheat and cotton, but not raw crops'

'Short-staffed and cannot regulate land application installations.'

This survey of the opinions and policies of state regulatory agencies on important facets of the land application process has shown that most states have, as yet, not come to grips with this alternative method of managing wastewaters effluents, This lack of definitive policies needs no defense; state agencies have been so deeply involved in the control of pollution resulting from the treatment of sewage and industrial wastes and the discharge of effluents of various qualities into surface water sources, that little time and staff personnel have been available to regulate land applicaton systems which have been limited in numbers and environmental impact.

The inferences of the 1972 amendments to the Federal Water Pollution Control Act will make more rigid evaluation of the methods and performance of land application systems essential, if the measure of reliability and capabilities of land application is to be properly assessed.

It was noted that many state agencies tended to conduct a demonstration project within their jurisdiction in order that an individual assessment of the effects of land application might be judged. Table 90, Partial List of Demonstration Projects Involving Land Application of Effluent or Sludge, lists the various studies which were disclosed by the survey investigations.

TABLE 89
STATE WATER POLLUTION CONTROL AGENCY RESPONSE

STATE	RULES/ STATUTES	INSTALL. REPORTED	PRETREAT. REQUIRED	DISTINCTION SEWAGE/I.W.	EFFLUENT QUALITY	STORAGE REQUIRED	STANDBY ACREAGE	BUFFER ZONES	AREA PROTECTION	SAFETY/ SAFEGUARDS	SEASONAL VARIATIONS
ALA. Water Impr. Comm.	None	None									
ALAS. Dept. Env. Cons.	Sec. 302 (a) & (f) Sub Ch. I Sec. 312(j)	None		None	Protect groundwater & water supply				Protect groundwater & water supply	Use of land or crops based upon type of treatment	
ARIZ. WPC & Health	Statute Art. 6 Part 4	Phoenix Tucson Small plants/golf	Secondary or tertiary—with disinfection	Ind. wastes secondary No disinf.; Sewage disinf.	BOD Susp.solids Coliforms Fecal coli					Use of land or crops based on degree of treatment	No refer.
CALIF. Dept.of Public Health	Adm. Code Title 17 Public Health	No inform.	Filtered & disinfected Oxidized & disinfected		For produce—MPN 22/100 ml.; fodder/seed orchards prim. effl.			No refer. Code covers quality only			
COLO. Water Resources Control Bd.	No specific regulations										
FLA. Dept. Poll. Control	None Could use for "experiment" purpose		Secondary plus disinf. BOD/SS Coliforms	No public contact with sew. effluent	BOD SS MPN						
HAWAII Dept. Health	No regulations	None listed	Protect water quality		Protect water standards of adequate treatment						

	GUIDELINES/DESIGN; O&M; OTHERS								
STATE	AREA	DOSE RATE	GROUNDWATER	SOIL CONDITION	TYPE OF APPLICATION	CROP/GRASS	MONITORING	OTHER	OFFICIAL COMMENTS
ALA.									"Not seen fit to dispose of treated or raw wastewater by irrigation."(John M. Bolton)
ALAS.									No problem. Regulations only for water protection. (Ronald G. Hansen)
ARIZ.						Crops based on degree of treatment			Robert H. Follett--gave information on Tucson, Phoenix and small plants.
CALIF.					Spray irrig. Surface irrig. Recreational improvement	Refers to fodder, fiber, seed, food, crops, pasture			No letter; code only.
COLO.							If wastewaters could reach surface or groundwater, no irrigation permitted		Denver disposes of sludge by land spreading. (Frank J. Rozick)
FLA.									Land disposal could be considered as "experimental use," with surety bond. (Dick Shelton)
HAWAII									(Wilbur S. Lummis, Jr.)

GUIDELINES/DESIGN; O&M; OTHERS

STATE	AREA	DOSE RATE	GROUNDWATER	SOIL CONDITION	TYPE OF APPLICATION	CROP/GRASS	MONITORING	OTHER	OFFICIAL COMMENTS
IND.									**Considers each application for spray irrigation or ground percolation as individual problem. (Perry Miller)**
MAINE									
MD.	**Use Pennsylvania State University criteria on unit loadings and methods of application.**								**Several other land disposal projects being considered. (W. McLean Bingley)**
MICH.									**(William G. Turney)**
MINN.	**Based on dosage rates**	**2 in./ac wk 1/2 in./hr 52 in./yr July-Aug. higher**	**10 in. to groundwater for underdrains, 1 in.**		**Spray and ridge and furrow**		**Wells 200 ft. outside area, 500 ft apart, 5 ft deep max. Quality tests specified.**	**Seepage basins preceded by tertiary treatment to remove N, etc.**	**No letter received. No comments.**
MONT.									**(D. G. Williams)**
NEB.	**No irrigation guidelines. Stabilization lagoons criteria include 25 lbs. BOD/acre; 150 persons/acre; 12,500 gal./acre**								**(T. A. Filipi)**

STATE	RULES/ STATUTES	INSTALL. REPORTED	PRETREAT. REQUIRED	DISTINCTION SEWAGE/I.W.	EFFLUENT QUALITY	STORAGE REQUIRED	STANDBY ACREAGE	BUFFER ZONES	AREA PROTECTION	SAFETY/ SAFEGUARDS	SEASONAL VARIATIONS
IND. Stream Poll.	Each proposal considered	1 city 16 industrial sites									
MAINE Dept. Health & Welfare		Vahlsing,Inc. Morning Star Prod.									
MD. Env. Health Admin.	None Use Pa. State U. criteria	1 Private sewage system 1 trailer camp									
MICH. Dept. Natural Resources	Not reported	Over 50 municipal & industrial sites									
MINN. WPC Agency	Design criteria issued		Secondary plus disin. BOD/SS Coliforms		BOD/SS Coliform Drinking water standards	Minimum of 210 days	Adequate area to assure no more than 2 in./week	Yes,thru purchase of land	Fence/signs Min. distance to water supply, sources, homes, parks		
MONT. Dept. Health	None Each case examined Individ.	4-5 small; Big Sky sew.; Ind. seepage	Secondary treatment Chlor. for golf course			Winter storage in holding ponds					
NEB. Dept. Envir. Control	No specific regulations	3 sites for lagoon effluent irrigation	Lagoons			Lagoons					

STATE	RULES/ STATUTES	INSTALL. REPORTED	PRETREAT. REQUIRED	DISTINCTION SEWAGE/I.W.	EFFLUENT QUALITY	STORAGE REQUIRED	STANDBY ACREAGE	BUFFER ZONES	AREA PROTECTION	SAFETY/ SAFEGUARDS	SEASONAL VARIATIONS
N.J. Dept. Envir. Protec.	No rules each site considered individually	Seabrook Farms; 4 sewage sites	Yes								
N.Y. Dept. of Envir. Conser.	No regul.; included in poll control	Indust. sites listed		Yes							
N.DAK. Dept. Health	No regul.	Lagoon most of state; Dickinson irrigation									
OKLA. Dept. Health	No regul. Now studying regulations	None reported Encourages for hay									
PA. Dept. of Environ. Res.	Spray Irrig. Manual No. 31	No inform.	At least secondary treatment	No reference	No specific components listed, except N/BOD	Storage, where land is "disrupted"	Yes,where land is "disrupted"	To protect against spray	No specific reference	No specific reference, except spray protection	Storage, where seasonal flow treatment is not continuous
R.I. Dept. Health	None	None									
S.DAK. Dept. Health	No regul. Each site considered individually	None reported									
TEXAS Water Quality Board	Health Dept. staff recommendations	None reported	Secondary treatment, plus 2-5 ppm Col. residual	No public contact with sewage effluent	BOD/SS/ MPN						
UTAH Social Serv. Health	Regulations on small underground disposal systems	Devils Slide & Echo used subsurface disposal	Rules apply to discharge of effluent to leaching fields								

	GUIDELINES/DESIGN; O&M; OTHERS								
STATE	AREA	DOSE RATE	GROUNDWATER	SOIL CONDITION	TYPE OF APPLICATION	CROP/GRASS	MONITORING	OTHER	OFFICIAL COMMENTS
N.J.									Location of facility, type of treatment and nature of land considered on merits. (Robert L. Vincent)
N.M.									Short staffed. Cannot supply data. Invitation to visit office. (John R. Wright)
N.Y.									(Willard H. Bruce)
N.DAK.									Have encouraged land disposal, but no success. Average lagoons dispose of 20-40 percent by seepage and evaporation.
OKLA.									Encourage land irrigation of well treated effluent for pasture, wheat, cotton. No eaten crops. (Charles D. Newton)
PA.	Must be enough to limit application to state standards	Max. 1/4 in./hr and 2 in./day 1 day/wk with 6 days' rest	At least 10 in. below ground level	Soil types listed. Irrig. rpt. must describe	Spray irrigation manual	Cover growth important. No reference to type crops	On all sites, monitoring wells, with or without pumps; in flow direction	Sprinklers elevated. Distributor spacing important	No letter; Manual only.
R.I.									(Walter J. Shea)
S.D.									(Gary Stephenson)
TEXAS					Subsurface irrigation favored	Reference to golf courses	Tailwater prohibited to ground or surface waters	All piping marked.	No objection to land application if properly controlled. (Robert G. Fleming
UTAH									Utah rules do not apply to "land disposal" by irrigation. (Calvin K. Sudweeks)

STATE	RULES/ STATUTES	INSTALL. REPORTED	PRETREAT. REQUIRED	DISTINCTION SEWAGE/I.W.	EFFLUENT QUALITY	STORAGE REQUIRED	STANDBY ACREAGE	BUFFER ZONES	AREA PROTECTION	SAFETY/ SAFEGUARDS	SEASONAL VARIATIONS
VA. Water Poll. Control Board	None reported	None listed	Covered by Water Pollution Control Law								
WASH. Dept. of Ecology	No rules Design criteria for sewage	No records of install.; Seattle	Lake Wash. refers to primary effluent. Clark County requires secondary disposal	Sewage rules only provided			Area equal to spray field	Lake Wash. only 200 ft. Clark Co. 100 ft., min.	Fencing No runoff from field Signs posted No livestock		
W.VA. Dept. Natural Res.	No spec. regulations; covered by WPC Law	Not practical Tannery uses land disposal				Short season limits land application					
WYO. Health and Social Serv.	No specific regulations on land disposal	Few cases of crop irrigation with effluent									

	GUIDELINES/DESIGN; O&M; OTHERS								
STATE	AREA	DOSE RATE	GROUNDWATER	SOIL CONDITION	TYPE OF APPLICATION	CROP/GRASS	MONITORING	OTHER	OFFICIAL COMMENTS
VA.									
WASH.		10,000 gal./ ground acre/ day	Percolation tests. No clay or hard-pan within 5 ft	Four soil percolation tests/acre	Oscillating-type sprinkler heads	Grass cover required. No pasturing permitted. Forage cut regularly	Monitoring of nearby water-course required	Spray field life limited to 5-7 years	Land disposal favored for Eastern Wash. Used only under special conditions in Western Washington. (Werner A. Hahne)
W.VA.									Mountainous terrain discourages land disposal. (Edgar N. Henry)
WYO.									No problems concerned with health and nuisance problems. (John F. Wagner)

TABLE 90
PARTIAL LIST OF DEMONSTRATION PROJECTS INVOLVING LAND APPLICATION OF EFFLUENT OR SLUDGE

Project	Location	Type/Identification	Funding	Status	Remarks
Beltsville Sludge	Md.	Sludge trenching	EPA	99% complete	
Beltsville Sludge	Md.	Sludge composting	USDA/MES	testing compost materials	
Cape Cod/Woodshull	Mass.	Hi-rate percolation/infiltration	EPA	Not started	different from Flushing Meadows climate
Chicago Prairie Plan	Ill.	Sludge-spray irrigation & dumping	Chicago	on-going	in operation in Fulton County
City of Belding	Mich.	Spray irrigation on forest land	EPA	on-going	
El Paso Meat Packing	Tex.	Spray irrigation, hi-organic (BOD)	EPA	on-going	
Flushing Meadows	Ariz.	Hi-rate percolation	USDA/EPA	on-going	different climate from Cape Cod
Lake County	Fla.	Land application	Soap & Detergent Assoc.		
Mich. State Univ.	Mich.	Lagoon effluents–aquatic plants	EPA*	on-going	Institute of Water Research
Muskegon County	Mich.	Spray irrigation WW on crops	EPA	not started	in operation in Fulton County
Oahu	Hi.	Land application			
Ocean Cnty, NJ Sludge	N.J.	Wastewater solids utilization on land	EPA/NJ*	not started	
Penn State Univ.	Penn.	Spray irrigation renovation of WW	PSU/EPA	on-going	
St. Petersburg	Fla.	Land application in urban areas			
Santee	Calif.	Recharge		completed	
Tallahassee Pollutant Removal	Fla.	Hi-rainfall, hi-water table	EPA	on-going	

Source: U.S.E.P.A.

EXHIBIT I

STATE OF ARIZONA, DEPARTMENT OF HEALTH RULES AND REGULATIONS FOR RECLAIMED WASTES

Article 6
Part 4

SEC. 6-4-1. GENERAL

REG. 6-4-1.1 LEGAL AUTHORITY

The regulations in this Part are adopted pursuant to the authority granted by Sec. 36-1854.3 and Sec. 36-1857, Arizona Revised Statutes.
(Added Reg. 1-72)

REG. 6-4-1.2 POLICY

The following regulations shall govern the direct reuse of reclaimed wastes, and all waste discharges into the waters of the State shall be in compliance with the "Water Quality Standards for Surface Waters in Arizona."
(Added Reg. 1-72)

REG. 6-4-1.3 APPLICABILITY

A. The direct reuse of wastes originally containing human or animal wastes is prohibited unless such wastes comply with the standards in this Part.

B. Nothing in this section shall be construed as an exemption from other applicable Rules and Regulations of the Arizona State Department of Health including but not limited to Reg. 2-2-4.9.
(Added Reg. 1-72)

SEC. 6-4-2. REQUIRED TREATMENT

REG. 6-4-2.1 SECONDARY

All wastes shall receive a minimum of secondary treatment or its equivalent before they are used for any of the following purposes:

A. Irrigation of fibrous or forage crops not intended for human consumption.

B. Irrigation of orchard crops by methods which do not result in direct application of water to fruit or foliage.

C. Watering of farm animals other than producing dairy animals.

REG. 6-4-2.2 SECONDARY AND DISINFECTION

A. All wastes shall receive a minimum of secondary treatment or its equivalent and disinfection before they are used for any of the following purposes:

1. Irrigation of any food crop where the product is subjected to physical or chemical processing sufficient to destroy pathogenic organisms.
2. Irrigation of orchard crops by methods which involve direct application of water to fruit or foliage.
3. Irrigation of golf courses, cemeteries and similar areas.
4. Watering of producing dairy animals
5. To provide a substantial portion of the water supply in any impoundment used for aesthetic enjoyment or for purposes involving only secondary contact recreation.

B. Following treatment specified in A. above, the monthly arithmetic average density of the coliform group of bacteria in the effluent shall not exceed 5,000 per 100 milliliters and the monthly arithmetic average density of fecal coliforms shall not exceed 1,000 per 100 milliliters. Both of these limits shall be an average of at least two consecutive samples examined per month during the irrigation season, and any one sample examined in any one month shall not exceed a coliform group density of more than 20,000 per 100 milliliters, or a fecal coliform density of more than 4,000 per 100 milliliters.
(Added Reg. 1-72)

EXHIBIT II

COLORADO DEPARTMENT OF HEALTH

RULES, REGULATIONS AND STANDARDS FOR CERTAIN DOMESTIC SEWAGE TREATMENT SYSTEMS AND OTHER NON-MUNICIPAL SYSTEMS OTHER THAN SEPTIC TANKS

I. **Authority**: Colorado Revised Statutes 1963, Section 66-1-7 (2), (5) and (6); 66-1-8 (5) (a) and 3-16-2, as amended (1967 and 1969 Perm. Cum Supps.)

Adopted: November 15, 1972

Effective Date: January 1, 1973

II. **Purpose**: The State Board of Health hereby finds and determines that it is necessary in the interest of public health, welfare and safety that uniform rules, regulations and standards be established to govern the discharge of liquid wastes from individually owned and operated domestic sewage treatment systems and other non-municipal systems, other than septic tanks, that discharge upon the surface of the ground, or where the discharge is underground but it erupts or seeps to the surface of the ground.

III. **Scope**: This regulation shall apply to all individually owned and operated domestic aerobic sewage treatment works and other non-municipal systems, other than septic tank systems as generally defined in the United States Department of Health, Education and Welfare *Manual of Septic Tank Practice*, public health publication 910.526, dated revised 1967.

IV. **Standards and Criteria**: Individually owned and operated domestic and non-municipal sewage treatment plants to which these regulations are applicable shall meet and conform to the following standards and criteria:

1. General Conditions

(a) The effluent shall be contained within the boundaries of the premises upon which the treatment plant is located and the discharge shall be sufficiently distant from inhabited premises to prevent the development of a nuisance condition.

(b) Effluents applied to the land shall be distributed over an area sufficient to absorb the total effluent flow and shall not be applied to edible crops.

(c) The treatment system shall provide an opening from which samples of the effluent may be conveniently obtained by authorized personnel, located at a point following aerobic treatment, settling chlorine contact or other method of disinfection approved by a health officer.

(d) A signal device shall be installed which will provide an obvious warning to indicate a failure or malfunction of any or all units of the total treatment system.

Exhibit II (continued)

2. Disinfection of the Effluent

(a) The system shall provide chlorine contact time of not less than sixty (60) minutes following aerobic treatment and settling.

(b) The effluent shall contain a chlorine residual at the sampling point of not less than one (1) milligram per liter.

(c) A method of disinfection other than by chlorine contact which is of equal efficacy and simplicity may be used if approved by a health officer.

3. Effluent Standards

(a) The effluent at the point of sampling consistently shall meet a standard 5-day biochemical oxygen demand (BOD) of less than twenty (20) milligrams per liter, based upon a grab sample collected at any time.

(b) The effluent at the point of sampling the chemical oxygen demand (COD) consistently shall be less than eighty-five (85) milligrams per liter, based upon a grab sample collected at any time.

(c) The effluent at the point of sampling consistently shall not have a fecal coliform density in excess of two (2) per one hundred (100) milliliters as recorded in terms of M.P.N., or as based upon a membrane filter count.

(d) The effluent at the point of sampling consistently shall contain total suspended matter (nonfilterable residue) of less than thirty (30) milligrams per liter, based upon a grab sample collected at any time.

4. Methods of Analysis

(a) All effluent samples shall be analyzed according to the methods described in the current edition of *Standard Methods for the Examination of Water and Waste Water* as prepared and published by: American Public Health Association; American Waterworks Association; Water Pollution Control Federation.

V. **Enforcement:**

1. Any individually owned and operated domestic aerobic sewage treatment works or other non-municipal systems within the purview of these regulations that is determined not to be in compliance therewith is hereby declared to be a public nuisance and shall be summarily abated by a cease and desist order or injunctive proceedings.

EXHIBIT III
STATE OF FLORIDA
DEPARTMENT OF HEALTH AND REHABILITATIVE SERVICES
DIVISION OF HEALTH

Requirements for Effluent Irrigation

The following safeguards shall be taken when treated effluent is to be utilized for golf course irrigation and/or areas where the public has access.

1. A certified operator shall be provided to supervise operation of system prior to its use.
2. The area irrigated with the effluent shall be irrigated only during periods when the mist will not come in contact with the public or players.
3. The wastewater entering the irrigation system shall be considered adequately disinfected if the median Most Probable Number (mpn) of coliform organisms does not exceed 23 per hundred milligrams of sample. On a weekly basis the mpn shall be determined and results submitted to the local county health department. These shall also be tabulated on the monthly operation reports submitted to this agency.
4. The plant effluent entering the irrigation system shall have a chlorine residual of not less than 1.0 mg/l.
5. There shall be an adequate buffer zone of at least 50 feet between any residential property and area to be irrigated.
6. It is preferred that the sprinkler heads be of the removable type whereby such heads will be manually inserted before commencing irrigation.
7. In the design of the sprinkler system, the piping shall be a separate system entirely, with no cross-connections to a potable water supply.

EFFLUENT DISPOSAL

A review of treatment facilities approved by the Division of Health during 1970 shows the following:

There were 378 treatment plants processed, all of which were designed to meet the State minimum 90% B.O.D. removal plus chlorination. In regards to effluent disposal, 242 of these systems were designed for no direct discharge of effluent to water courses. Effluent was disposed of by evaporation-percolation ponds, irrigation systems or subsurface drainfields.

The Division of Health's current concern in the review of these type systems stems from the need to protect the public health and requirements would vary depending on the type of system proposed.

I. Evaporation-Percolation Systems
The public health concern of these systems is that adequate distance and soil types must be available to protect all potable water supplies in the area. Therefore, the pond should be

Exhibit III (continued)

located so as not to affect the underground water used as water supply source and not create a nuisance to other property owners. The pond should be fenced to keep out the general public. The size of pond will depend on soil type and ability to dispose of water by percolation and should be designed large enough to prevent overflow. If failure of evaporation-percolation pond occurs, the emergency discharge of well-treated-chlorinated effluent from the pond should be to a point which will not create a health hazard as it relates to recreational waters, shellfish waters, or public water supplies, and also not create a nuisance, until additional pond area and/or irrigation area is made available.

II. Irrigation Systems
(These systems have all been designed for effluent disposal and not plant growth.)

a) Irrigation of areas where the general public does not come in contact and the aerosol drift will not leave the irrigation area. The public health concerns are the same as for the Evaporation-Percolation systems.

b) Irrigation of public areas (Golf courses, Parks, etc.)
The following safeguards shall be taken when treated effluent is to be utilized for golf course irrigation and/or areas where the public has access:

1. A pond at the plant site with a detention time of 1½ to 3 days shall be provided prior to discharge to irrigation system.

2. A certified operator shall be provided to supervise operation of system prior to its use.

3. The area irrigated with the effluent shall be irrigated only during periods when the mist will not come in contact with the public or players.

4. The waste water entering the irrigation system shall be considered adequately disinfected if the Median Most Probable Number (mpn) of coliform organisms does not exceed 23 per hundred milligrams of sample. On a weekly basis, the mpn shall be determined and results submitted to the local county health department. These shall also be tabulated on the monthly operation reports submitted to this agency.

5. The plant effluent entering the irrigation system shall have a chlorine residual of not less than 1.0 mg/l.

6. There shall be an adequate buffer zone of at least 50 ft. between any residential property and area to be irrigated. The spray should not reach walkways, parking areas, play areas, drinking fountains or other similar areas.

7. It is preferred that the sprinkler heads be of the removable type whereby such heads will be manually inserted before commencing irrigation.

8. In the design of the sprinkler system the piping shall be a separate system entirely, with no cross-connections to a potable water supply.

c) Irrigation of Athletic Fields/Playgrounds - NOT RECOMMENDED, but considered where field is closed to use and not used for 30 days after irrigation ceases.

EXHIBIT IV
STATE OF TEXAS

RECOMMENDATIONS FROM THE STAFF OF THE DIVISION OF WASTEWATER TECHNOLOGY AND SURVEILLANCE WHEN THE DOMESTIC WASTEWATER EFFLUENT IS TO BE USED FOR IRRIGATION OF AREAS ACCESSIBLE TO THE PUBLIC

1. Effective wastewater treatment facilities should be provided, operated, and maintained continuously in order that the wastewaters used will not exceed 20 ppm total Suspended Solids content, and a MPN (Most Probable Number of Coliform organisms per 100 ml) value of not more than 50.

2. To achieve the recommended bacterial quality of the effluent will probably require a chlorine residual of 2.0 to 5.0 ppm for a contact period of 20 minutes at peak flow conditions immediately prior to the application of the wastewater to vegetation. Rechlorination will be required when effluent is stored in holding ponds or oxidation ponds subsequent to chlorination at the plant and prior to its application as irrigation water.

3. Irrigation should never be practiced at times that the areas are open to the public.

4. Sub-surface irrigation systems would present a lesser public health hazard than the use of spray systems.

5. Laboratory examination on effluent samples should be made at such a frequency as to be assured that the recommended quality parameters are attained and maintained.

6. Records should also be maintained showing periods of applications, as well as laboratory examination results.

7. All wastewater outlets and pipes should be marked plainly to show the presence of contaminated water, and also all outlets or valves should be protected to prevent their operation only by authorized individuals.

8. These recommendations are offered, assuming such re-use of the wastewater treatment plant effluent meets with the approval of the local health officer.

9. Areas which are irrigated by sewage effluent should be separated by a minimum distance of 500 feet from wells supplying water for drinking purposes or water supply treatment plants.

10. The system of piping used to distribute sewage effluent to points of application for irrigation purposes shall have no physical connection with a drinking water supply system

11. Irrigation systems shall not be installed in locations where dairy farms will be adversely affected.

12. The owner should contact the local health authorities and inform them of his sewage disposal program and its relationship with other elements of the establishment.

January 21, 1972

Exhibit IV (continued)

TO WHOM THIS MAY CONCERN

By authority vested in the Commissioner of Health by Articles 4465A and 4466 to make, publish and enforce rules consistent with this law, and adopt standards for foods, food products, beverages, drugs, etc., and the modern methods of analysis authorized as official by the Federal Department of Agriculture, I hereby make and adopt the following rules and standards for food crops which might be consumed in the raw state.

> "The use of raw or partially treated sewage or the effluent from a sewage treatment plant is prohibited for use as irrigation water on any food crop which might be consumed in the raw state. Such practice is the deliberate exposure of food to filth as defined by paragraph (a) 4-Section 10, Art. 4476-5 of our civil statutes."

J. E. Peavy, M.D.
Commissioner of Health

Approved by the State Board of Health at its regular meeting held at Austin, Texas, December 11, 1961.

EXHIBIT V
GREAT LAKES–UPPER MISSISSIPPI BOARD

ADDENDUM NO. 2
TO RECOMMENDED STANDARDS FOR SEWAGE WORKS
(1968 EDITION)

APRIL 1971

GROUND DISPOSAL OF WASTEWATERS

Interest has been expressed in the development of guidelines for engineering review of proposed projects for ground disposal of wastewaters.

There are apparently relatively few known large-scale installations of spray irrigation systems and very limited data available within the 10 GLUMRB states.

The protection of groundwater and surface resources is the major concern in the development of guidelines. However, quality of groundwater discharged to surface waters also must be considered the water quality criteria.

Practices must be established which will prevent wastes of any nature from being introduced into the fresh groundwaters which will so change their characteristics as to make them unsuitable for potable water supply or other present and future usage.

The priority of the water usage is subject to the jurisdiction of the appropriate state and local regulatory agencies.

Preliminary Considerations

Ground disposal installations are normally used where the waste contains pollutants which can successfully be removed through distribution to the soil mantle. These pollutants can be removed through organic decomposition in the vegetation-soil complex and by adsorptive, physical, and chemical reactions with earth materials. Preliminary considerations of a site for ground disposal should be the compatibility of the waste with the organic and earth materials and the percolation rates and exchange capacity of the soils. The ground disposal of wastewater will eventually recharge the local groundwater; therefore, the quality, direction and rate of movement and local use of the groundwater, present and potential, are prime considerations in evaluating a proposed site.

It is essential to maintain an aerated zone of at least five feet and preferably more, to provide good vegetation growth conditions and removal of nutrients. It must be realized a groundwater mount will develop below after it is in use. The major factors in design of ground disposal fields are topography, soils, geology, hydrology, weather, agricultural practice, adjacent land use and equipment selection and installation.

Design Report

The design report shall include maps and diagrams as noted below. It shall also include any additional material that is pertinent about the location, geology, topography, hydrology, soils, areas for future expansion and adjacent land use.

Location

(1) A copy of the U.S.G.S. topographic map of the area (7 ½-minute series where published) showing the exact boundaries of the spray field.

(2) A topographic map of the total area owned by the applicant at a scale of approximately one inch to 50 feet. It should show all buildings, the waste disposal system, the spray field

boundaries and buffer zone. An additional map should show the spray field topography in detail with a contour interval of two feet, and include buildings and land use on adjacent lands within ¼ mile of the project boundary.

(3) All water supply wells which might be affected shall be located and identified as to uses; e.g., potable, industrial, agricultural, and class of ownership; e.g., public, private, etc.

(4) All abandoned wells, shafts, etc., shall be located and identified. Pertinent information thereon shall be furnished.

Geology

(1) The geologic formations (name) and the rock types at the site.

(2) The degree of weathering of the bedrock.

(3) The local bedrock structure including the presence of faults, fractures and joints.

(4) The character and thickness of the surficial deposits (residual soils and glacial deposit).

(5) In limestone terrain, additional information about solution openings and sinkholes is required.

(6) The source of the above information must be indicated.

Hydrology

(l) The depth to seasonal high water table (perched and/or regional) must be given, including an indication of seasonal variations. Static water levels must be determined at each depth for each aquifer in the depth under concern. Critical slope evaluation must be given to any differences in such levels.

(2) The direction of groundwater movement and the point(s) of discharge must be shown on one of the attached maps.

(3) Chemical analyses indicating the quality of groundwater at the site must be included.

(4) Indicate the source of the above data.

(5) The following information shall be provided from existing wells and from such test wells as may be necessary:

(a) Construction details–where available: Depth, well log, pump capacity, static levels, pumping water levels, casing, grout material and such other information as may be pertinent.

(b) Groundwater quality: e.g., nitrates, total nitrogen, chlorides, sulphates, pH, alkalinities, total hardness, coliform bacteria, etc.

(6) A minimum of one (1) groundwater monitoring well must be drilled in each dominant direction of groundwater movement and between the project site and public well(s) and/or high capacity private wells with provision for sampling at the surface of the water table and at five (5) feet below the water table at each monitoring site. The location and construction of the monitoring well(s) must be approved. These may include one or more of the test wells where appropriate.

Exhibit V (continued)

Soils

(1) A soils map should be furnished of the spray field, indicating the various soil types. This may be included on the large-scale topographic map. Soils information can normally be secured through the USDA Soil Conservation Service.

(2) The soils should be named and their texture described.

(3) Slopes and agricultural practice on the spray field are closely related. Slopes on cultivated fields should be limited to 4% or less.
Slopes on sodded fields should be limited to 8% or less. Forested slopes should be limited to 8% for year-round operation, but some seasonal operation slopes up to 14% may be acceptable.

(4) The thickness of soils should be indicated. Indicate how determined.

(5) Data should be furnished on the exchange capacity of the soils. In case of industrial wastes particularly, this information must be related to special characteristics of the wastes.

(6) Information must be furnished on the internal and surface drainage characteristics of the soil materials.

(7) Proposed application rates should take into consideration the drainage and permeability of the soils, the discharge capacity, and the distance to the water table.

Agricultural Practice

(1) The present and intended soil-crop management practices, including forestation, shall be stated.

(2) Pertinent information shall be furnished on existing drainage systems.

(3) When cultivated crops are anticipated, the kinds used and the harvesting frequency should be given; the ultimate use of the crop should also be given.

Adjacent Land Use

(1) Present and anticipated use of the adjoining lands must be indicated. This information can be provided on one of the maps and may be supplemented with notes.

(2) The plan shall show existing and proposed screens, barriers, or buffer zones to prevent blowing spray from entering adjacent land areas.

(3) If expansion of the facility is anticipated, the lands which are likely to be used for expanded spray fields must be shown on the map.

Treatment Before Land Disposal

In general, the equivalent of secondary treatment will be required. All wastes must be amenable to treatment by the soil prior to application. All wastes to be spray irrigated shall be disinfected. Disinfection may be required for other types of irrigation. Screening shall be provided in all cases where solids are expected of a size equal to or greater than the nozzle hole diameter.

Exhibit V (continued)

Storage shall be provided to the maximum capacity required to accomodate flows in excess of quantities to be irrigated.

Piping to Sprinklers

The piping should be so arranged to allow the irrigation pattern to be varied easily. Stationary systems are preferred; but if a moveable system is proposed, one main header must be provided with individual connections for each field and sufficient spare equipment must be available to assure noninterrupted irrigation. Facilities must be provided to allow the pipes to be completely drained at suitable points to prevent pollution and freezing.

Sprinkling System

Sprinklers must be so located as to gve a nonirrigated buffer zone around the irrigated area and design of the buffer zone must consider wind transport of the wastewaters. The system shall be designed to provide an even distribution over the entire field.

The application rate must be selected low enough to allow the waters to percolate into the soil and to assure proper residency within the soil mantle. Proposed application rates will not be accepted without substantiating data.

In general, sufficient monitoring controls should be provided to indicate the degree of efficiency with which the sprinklers are working. A pressure gauge and flow meter should be provided.

Runoff

The system shall be designed to prevent surface runoff from entering or leaving the project site.

Fencing

The project area shall be enclosed with a suitable fence to preclude livestock and discourage trespassing. A vehicle access gate of sufficient width to accommodate mowing equipment should be provided. All access gates should be provided with locks.

Warning Signs

Appropriate signs should be provided along the fence around the project boundaries to designate the nature of the facility and advise against trespassing.

Bibliography: Agricultural Utilization of Sewage Effluent and Sludge, an Annotated Bibliography, Federal Water Pollution Control Administration, U.S. Department of the Interior, January, 1968.

SECTION V
SUMMARY OF FOREIGN EXPERIENCE

The use of wastewater land application methods is prevalent in many parts of the world. The methods employed, however, may vary in detail as to the quantity or quality of wastewaters, the degree of pretreatment, the manner of storage and application to the land, or to the types of vegetation grown. The essential purposes of land application remain: the effective disposal of wastewaters; and the exploitation of these wastewaters to secure the highest level of related benefits.

Land application in this country shares these basic purposes. This makes the investigation of foreign experience of value to this study. The American Public Works Association, as a resource organization to the United Nations on behalf of the United States, has access to the sources of this information. The salient features of this investigation follow.

The exploration of land application practices in other countries uncovered some relevant facts concerning these systems. The approach to land application taken in different countries often assumes a varied character based on the relative priorities of the related benefits being sought.

One basic aspect of land application relates to its capacity to enhance wastewater quality. This capacity derives primarily from the physical, chemical, biological and mechanical processes inherent within soils that come into play during the land application process and result in some level of additional treatment. In England, land application assumes a character of sophistication as a means of wastewater quality enhancement. It finds limited use as a method to achieve wastewater quality equivalent to tertiary treatment. This involves the surface application of secondary treatment effluents on sloping grasslands.[1] In Argentina, the treatment aspects of land application take on a somewhat different significance. Unchlorinated domestic wastewater lagoon effluents are employed for land irrigation in some parts of the country.[2] Finally, in India, land application of raw domestic sewage accounts for the majority of treatment for 40 percent of the 550 mgd of wastewater produced by sewered communities. This occurs on 132 farms, amounting to 30,902 acres in all parts of the country.[3]

Another related benefit concerns wastewater irrigation as a means to produce a more favorable balance between reliable water sources and the anticipated water demands of agricultural, industrial, power generation and domestic uses. As may be anticipated, wastewater application in this water resource management role occurs readily within the arid parts of the world. In the case of Israel, it is estimated that the total water resources of that country from all natural sources will supply about 437,000 million gal/year. . . . . The figure used for planning purposes is based on a future population estimate of 3 million with a total urban water use of some 80,000 million gal/year. It is estimated that only 85 percent of the urban water supply is recoverable as wastewater, and that only 60 percent of the national sewage flow will be utilizable in economically feasible projects. . . . . This amount will supplement the national water resources by 10 percent, bringing the total national water reserves to 477,000 million gal/year.[4]

A similar situation, although less cogently stated, occurs in Argentina where raw sewage land application has been recommended for use in reforestation projects in the arid parts of the country.[5]

Still another related benefit involves the economic impact of heightened agricultural and meat animal production related to the use of crop irrigation. This derives from the exploitation of wastewater as a consistent source of irrigation water and also as a source of crop nutrients. Investigations of crop production employing both domestic wastewaters and the wastewaters of specific industries have been taking place in Hungary with positive results among some crop types.[6]

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In Israel, a number of large-scale sewage irrigation schemes have also been developed in the Jerusalem area. All these projects have been carried out within the restrictions of the Ministry of Health sewage irrigation regulations and have in general produced excellent results from the agricultural viewpoint; research carried out in Israel has indicated that the yield from sewage-irrigated plots is significantly higher than comparable plots irrigated with normal water and provided with equivalent amounts of chemical fertilizer alone.[7]

It is evident from the foregoing that the emphasis associated with wastewater land application in different countries often takes somewhat different forms, consistent with national or regional goals. The essential characteristics and requirements of land application, however, remain similar in all parts of the world.

Climatic Influence

Perhaps the most succinct statement on climatic influence or the applicability of land application in terms of climate and agricultural productivity comes from Hungary. In areas, where the natural precipitation is small, wastewaters are used for irrigation to utilize more efficiently the energy sources of the soil in the interest of better produce and by making the amount of water necessary for a good yield available at any time in order to provide for good production and to decrease to a minimum the damages resulting from the lack of water. Where the precipitation is sufficient, the main purpose of irrigation is wastewater disposal. The production increase under these conditions is generally smaller than in the previous case, since this can be mainly attributed to the fertilizing effect of the wastewater. . . .[8]

The foregoing comments, as noted, represent an orientation towards agricultural enhancement as a related benefit of wastewater irrigation. Other climatic orientations concerning land application as an effective water resource management tool appear within the preceding discussion of goals and their related benefits.

In view of these considerations, it generally appears that these two considerations are closely related. The necessity for careful water resource management within arid climates appears to be followed closely by the use of land application among industrializing nations and then the exploitation of its agricultural enhancement potentials.

The Source of Wastewater

The wastewater sources in the land applications studied from other countries derived from both domestic uses and industrial processes. As previously noted, in India, 220 mgd of raw domestic wastewater is disposed of by land application with no dilution or treatment. Attempts are being made to employ dairy wastes and paper and pulp mill wastes for this purpose after preliminary treatment.[9] The Werribee Farm, operated by the Melbourne and Metropolitan Board of Works in Australia, treats from 96 to 250 mgd of domestic wastes on 17,243 irrigable acres. Eighty percent of this flow receives preliminary settling and 20 percent is applied untreated.[10] Mixed domestic and industrial wastes - including petroleum refinery wastes - from the Mexico City area irrigate 111,746 acres in the State of Hidalgo.[11]

Investigations of the land application of fruit and vegetable canning wastewaters have taken place in both Hungary and Belgium[12,13] and other parts of Europe. Work is also being performed on the use of industrial wastewaters from sugar refining, linen and hemp processing and other industries, as well as from domestic sources. The use of industrial wastewaters depends upon the processes involved, and careful investigation of wastewater quality must be performed to determine its suitability for irrigation purposes.

Land application also occurs on a number of individually operated sites as part of normal irrigation operations. Under these circumstances, wastewaters are introduced into existing irrigation water supplies or provided as an alternative irrigation source to individual growers. The capacity to control the use of wastewater and the application site diminishes with the degree to which the land application process is generalized.

Wastewater Quality and Treatment

Philosophical differences concerning acceptable characteristics for wastewaters arise as a result of different attitudes towards the related benefits of land application - wastewater quality enhancement, wastewater irrigation as a water resource management mechanism or as a source of improved agricultural production.

From the point of view of water quality management, the wastewaters employed for land application must be of relatively high quality prior to their use. This philosophy imposes the need for preliminary treatment to a high level, often represented by quality parameters consistent with those applicable for the discharge of wastewater to surface receiving waters.

The point of view expressed on behalf of improved agricultural production is represented by the following: Wastewater treatment for agricultural use is quite different from that of sewage treatment for disposal into receiving bodies of water. For agricultural irrigation, the reduction in BOD is of little significance. When effluents are being used for industrial crops, or for other crops which are to be processed before consumption, minimal primary treatment and an adequate reduction in suspended solids will be sufficient to allow for spray irrigation; it is assumed that there is little significant pathogen removal, and the low level of BOD reduction plays no significant role.[14]

With these apparent differences in existing attitudes on the quality of wastewaters for land application in mind, the information received concerning quality and treatment on a national basis appears below.

a. Australia

At the Board of Works Farm at Werribee, wastewater flows amount to an average of 96 mgd from both domestic and industrial sources in Melbourne. Eighty percent of these wastewaters are subject to sedimentation. These wastewaters have a BOD of 600 ppm, suspended solids of 500 ppm, and a chloride ion concentration of 400 ppm.

Other land application sites exist in Victoria, Australia, at Braeside, Dutson Downs, and among many small communities in the northern part of the state. Information on these facilities has not been reported. Investigations have been conducted concerning the use of wastewater effluents from the South-Eastern Wastewater Purification Plant in Victoria. Up to 64 mgd of secondary treatment effluent could be made available for this purpose. The anticipated quality of this wastewater follows:

Total dissolved solids	700 mg/l
Sodium as Na	130 mg/l
Sodium adsorption ratio	3.2
Chloride as Cl	2/5 mg/l
Phosphorus as PO4	20 mg/l
Nitrogen as N	30 mg/l
Boron as B	0.5 mg/l

These figures represent the peak levels anticipated for planning purposes.

b. India

In general, there are no quality conditions or data available concerning the domestic wastewaters employed for land application. Standards exist for industrial wastewaters, as compiled by the Indian Standards Institution. These are presented below:

Tolerance Limits for Industrial Effluents Discharged on Land for Irrigation Purposes (Indian Standards Institution I.S. 3304-196S)

Characteristics	
pH	5.5 - 9.0
Total dissolved solids	2100 mg/l
Sulfates	1000 mg/l
Chloride (as Cl)	600 mg/l
Percent sodium	60%
BOD_5	500 mg/l
Oils and grease	30 mg/l
Boron (as B)	2.0 mg/l

c. Israel

Anaerobic and aerobic oxidation ponds

provide treatment in Israel for both domestic and industrial wastewaters prior to land application. Stabilization ponds of short detention periods from five to seven days and high loading have been used in more than 100 land application installations. Further data on quality parameters are not available.

d. Mexico

Industrial and domestic wastewaters have long been discharged to the canal system draining Mexico City. This system provides a source of irrigation water in El Mezquetal, Hidalgo. The wastewaters involed are a mixture of raw and treated effluents; the resulting average quality of the irrigation water at the point of use is as follows:

BOD	244 ppm
DO	O.4 ppm
COD	228 ppm
Total Solids	1,623 ppm
Total dissolved solids	1,209 ppm
Suspended solids	414 ppm
Nitrogen	
organic	1.8
as NH_3	15.7
NO_2	0.015
NO_3	0.2
pH	8.0
Alkalinity as $CaCo_3$	472
Carbonate	9
Bicarbonate HCO_3	555
Chlorides	236
Sulfate	95
Sodium	321
Calcium	43
Magnesium	22
Boron	0
ABS	12.4

e. Hungary

The characteristics of raw domestic wastewaters used experimentally and in limited land application systems are indicated in the attached table. Under Hungarian regulations, these raw domestic wastewaters must be subject to minimum treatment by sedimentation. The process requires a minimum detention time of 1-1/2 hours in a settling basin of 2 millimeters per second flow velocity. On this basis, a BOD reduction of up to 40 percent, a suspended solids reduction of up to 70 percent, and a bacterial reduction of up to 75 percent are predicted.

In general, irrigation wastewater quality requirements depend on soil composition and nutrient needs. Industrial wastewaters from the canning industry contain up to 3,500 mg/l of organic substances, up to 155 mg/l of potassium, relatively low nitrogen levels of 16 to 39 mg/l, relatively low phosphorus (P_2O_5 = 1.2 - 11.9 mg/l) content and dissolved inorganic substances that can approach high but not dangerous levels during canning operations. Among sugar refinery wastewaters, dissolved minerals of 1,000 to 3,000 mg/l were found as well as relatively high levels of calcium and potassium (K_2O = 110-140 mg/l). Sodium also appears but not in sufficient quantities to rule out its use. Useful nitrogen exists from 30 to 60 mg/l, and up to 5,000 mg/l of organic material can be expected. Wastewaters from the alcohol and beer industries, fiber processing, and from starch production have also been found to be suitable for irrigation purposes. The major determinants as to the applicability of industrial wastewaters appear to be the dissolved mineral content and sodium levels. Control of sodium levels appear to be by significant dilution.

CHARACTERISTIC QUALITY DATA AVERAGES OF THE WASTEWATERS OF TWO HUNGARIAN TOWNS

No.	Examined Components		1	2
1	pH		7.7	7.4
2	Total dissolved material	mg/l	1,602	1,112
3	Total suspended material	mg/l	702	218
4	Total dry matter	mg/l	2,304	1,330
5	Total organics	mg/l	1,040	543
6	Dissolved organics	mg/l	358	401
7	Suspended organics	mg/l	682	142
8	Total minerals	mg/l	1,264	787
9	Dissolved minerals	mg/l	1,144	711
10	Suspended minerals	mg/l	120	76
11	Oxygen consumption	mg/l	796	401
12	BOD_5	mg/l	194	60
13	Total nitrogen(N)	mg/l	20.0	21.0
14	Total phosphorus (P_2O_5)	mg/l	4.0	5.9
15	Total potassium (K_2O)	mg/l	40.0	32.6
16	Chloride (Cl^-)	mg/l	268	98
17	Sulfate (SO_4)	mg/l	149	345
18	Conductivity	mg/l	2,730	1,252

Source: Utilization of Urban Sewages for Irrigation
Vermes, Hungary

f. Belgium

Information on raw fruit and vegetable canning wastewaters appears as a result of experimentation in Belguim. The raw wastewater data follow:

BOD	720-848 mg/l
COD	1,650-1,220 mg/l
Suspended Material	45-70.5 mg/l
Organic Suspended Materials	42-61 mg/l
O_2	0.45-1.2 mg/l
Total Material	1,310-1,905 mg/l
Organic Materials	631-1,015 mg/l
pH	4.75-4.5
NH_4	4.2 mg/l
NO_2	0.11 mg/l
NO_3	3.6 mg/l
Organic Nitrogen	56.2 mg/l
Total Nitrogen	64.1 mg/l
PO_4	11.1 mg/l

In the experiments in question, these wastewaters were subject only to screening prior to their use as irrigation water.

The significance of some of the qualitative parameters relate to the nutrient values inherent in the wastewaters used for irrigation. The levels of organic content, nitrogen and phosphorus are important in this regard.

Other parameters are significant for the negative effects they represent when they exist in significant quantities. Total dissolved solids of very high levels can cause vegetation and crop damage. Total dissolved solids represent calcium, magnesium, sodium, and potassium cations, among others, as well as carbonate, sulfate, chloride and nitrate anions. Total dissolved solids are important because of the degree of salinity and sodium they represent. Other ions such as potassium, calcium and phosphorus are essentially beneficial. Low levels of salinity generally pose few problems. Medium to high salinity wastewaters may be used with plants tolerant to the existing levels. In addition, the application site must be well drained and other water sources–precipitation and other low salinity irrigation water–must be used to wash the soils and leach the salinity down below the root levels of the plants. High chlorides also present the potential of crop damage. High sodium levels can also damage sensitive plants - avocados and fruits with pits - and can affect the structure of clay soils. Sodium problems may be diminished by washing of the soils and by dilution, the addition of organic matter and calcium sulfate in some circumstances. Wastewaters with high sodium levels generally cannot be used for irrigation except when associated with low levels of salinity.

Boron is necessary for crop growth below given safe levels and becomes dangerous to crops above these levels. The limits of boron in irrigation waters appear in Table 91. Boron must be controlled at low levels as a tendency for some buildup in the soil exists.

Care must be taken to assure that wastewater for irrigation purposes contains no harmful or toxic substances - detergents, phenols, and others. The degree of toxicity of wastewaters should be verified by careful tests on plants. Other tests should be performed to determine the effects of wastewaters on soils, and to determine the degree of dilution or chemical rehabilitation of the wastewaters and, finally, the amount of supplementary nutrients necessary to build up the soils used.

Site Conditions and Wastewater Application

The character of the site, coupled with the mode of operations, represents the difference between an effective, well-managed system and one that is not. A summarization of the practices in other countries follows:

a. Hungary.

Site Conditions. The requirements for land application sites in Hungary derive from the need to locate a suitably sized area with appropriate soil conditions and soil quality. Soil quality relates to its chemical makeup and its relative evaluation with respect to the chemical analysis of the wastewaters to be employed, on the basis of enhanced agricultural production. The soils analysis minimizes hazards that might otherwise develop from the wastewater application process. Another important consideration involved concerns year-round and continuous wastewater disposal. Year-round disposal is accommodated through well-designed rotation plans employing acreage of perennial grasses, wooded areas and porous catchment acreage. In addition, the land application site must include protective, wooded buffers to provide site separation from other

TABLE 91
UNITS OF BORON IN IRRIGATION WATERS FOR AGRICULTURAL PRODUCTS WITH DIFFERENT GRADES OF TOLERANCE

Tolerant	**Semi-tolerant**	**Sensitive**
4 ppm	**2 ppm**	**1 ppm**
Asparagus	Sunflower	Mexican Oak
Palm Trees (Phoenix Canariensis)	Potato	Black Oak, Persian or English
	Cotton	
Date (Phoenix Tytiferia)	Tomato	Tuberous Sunflower
	Sweetpea	White Beans
Sugar Beets	Radish	American Elm
Beet		Plum
Betabel	Olive	Pear
Alfalfa	Barley	Apple
Gladiola	Wheat	Grape
Bean	Corn	Fig
Onion	Oats	Nispero
White Radish	Calabash	Cherry
Cabbage	Sweet Potato	Peach
Lettuce	Lima or Kidney Beans	Apricot
Carrot		Blackberry
		Orange
		Avocado
		Grapefruit
		Lemon
2 ppm	**1 ppm**	**0.3 ppm**

Source: Analysis of the Black Waters of the Cuenca of the Valley of Mexico and the Region of El Mezquital, Hidalgo–Bulletin 2 Hydraulic Commission of the Cuenca of the Valley of Mexico, Mexico, D.F., March 1965

development. The site must be located at least 300 meters from the closest residential districts. Groundwater levels must be at least 1.5 meters below the surface of the application site.

Methods and Rates of Application. Land application operations must be continuous and year-round. Application during the winter has not provided any difficulties in extreme cold and despite thick layers of snow. The most effective winter application, however, requires fall plowing of the site. Winter irrigation resulted in more favorable yields of potatoes and sugar beets. On the other hand, spring irrigation resulted in earlier and stronger grasses. Winter application amounted to an average of 220 to 225 mm. Filter meadows and forests with border levees may be irrigated to a 3,000–mm per year application rate, or less, to produce a desirable filtering effect.

The methods of wastewater application can be either by surface methods–ridge-and-furrow–or by spraying. Normal application rates were found to be between 300 mm to 600 mm per year for the medium heavy clays and sandy loams irrigated. Irrigation of alfalfa, corn and cereal is performed for four days on an 18- to 24-day cycle. Tree plantations can be irrigated at a rate of 80 mm every 15 to 20 days year-round to a total annual irrigation of 1,500 mm.

Ground Covers. Domestic wastewaters provide the best source of agricultural production for ground covers of fodder, pasturage, sugar beets, industrial crops, medicinal and decorative plants and popular trees. These types of ground cover are limited, due to the various regulations imposed for the use of domestic wastewater irrigation. Under these regulations, timber trees, forests, meadows and pastures may be irrigated in other than the growing season; plowed lands may be irrigated prior to sowing. Hungarian regulations do not limit the use of ground covers that may be employed with industrial wastewater irrigation.

b. Israel

Site Conditions. Information on land application sites in Israel is limited. Certain site requirements exist concerning public protection. Warning signs are required for areas being irrigated with wastewaters. Irrigation pipe lines should not be cross-connected to potable water supplies. Mosquito and fly control measures and odor control measures must be instituted on the irrigation site and at adjacent areas. Lawn irrigation can only occur when the lawns are closed to the public.

Separation of irrigation sites and other land uses depend on the method of application used. Ridge-and-furrow irrigation requires 100-meter separation from residential uses and 25-meter separation from roads, as a minimum. Spray irriation – defined as irrigation by spraying where no direct contact between the irrigation water and the plants and trees irrigated exists – requires 200-meter separation from residential areas and 50-meter separation from roads.

Ground Covers. The crop types allowed for ground cover formerly included watermelons, nuts, ground-nuts, sweet potatoes, okra, bananas, citrus fruit, olives, eggplant, melons, trees for landscaping, flowers, marrows, date trees and potatoes. In addition, crops for industrial and not human consumption, nursery trees, fodder crops and pasturage are employed as ground cover in Israel. Fruit tree or chards and grassed lawns may also be used under strictly controlled conditions.

As a result, with Israel's experience with the 1970 cholera epidemic, the government has prohibited the use of wastewater irrigation on food crops and is presently restudying its wastewater irrigation regulations.

c. India

Limited data exist concerning site conditions and the methods and rates of application of wastewater. Raw sewage irrigation is recommended only for those sites with light soils and excellent drainage. An indication exists that surface flooding represents one of the principal wastewater application methods.

Ground Covers. In India, fodder grasses, cereals, pulses, oilseed plants, cotton, sugarcane and various vegetable crops provide the majority of ground covers used on the site. An effort is being made to restrict ground covers to nonedible crops and the production of oil-bearing plants such as citronella, mentha, palmarosa, and lemon grass on farms irrigating with untreated domestic wastewaters.

d. Australia

Site Conditions. The most favorable site conditions indicated in Australia concern adequate area with suitable soils and contours, low rainfall and high evaporation, isolation from centers of population and isolation from points of groundwater withdrawal. In general, the investigation of irrigation sites considers a variety of factors. Among these are the quality and quantities of existing water, comparative analysis between existing water and wastewaters, quality and quantity evaluation of prospective application sites as to rainfall and evaporation topography, soil percolation and permeability, soil chemistry, site drainage, possible effects of wastewater irrigation, and potential crops.

An example of soil category classification in terms of application method, local drainage and crop type appears in Table 92, Irrigation Potential of Soil Types, from an interim report investigating the use of secondary effluents for irrigation purposes in Victoria, Australia.

TABLE 92
IRRIGATION POTENTIAL OF SOIL TYPES

Class	Expected Permeability	Method of Irrigation	Drainage Needs	Possible Crops
1	High	Sprinkler	Liable to waterlogging. Respond to tile drainage	Vegetables Flowers Lemons Lucerne (Probably nutrient deficiencies)
2[1]	Surface medium to high. Subsoil low to very low.	Sprinkler	Very liable to waterlogging Respond to close tile drainage	Vegetables Flowers Pasture (Possible nutrient deficiencies)
3	Surface low to medium. Subsoil low to very low.	Sprinkler or flood	Liable to waterlogging. Fair response to intense tile drainage	Orchards Vegetables Flowers Pasture
4	Surface low. Subsoil low to very low.	Flood	Liable to surface waterlogging	Pastures
5	Surface low to very low. Subsoil probably low.	Flood	Liable to surface waterlogging	Pastures
6[2]	Surface low to medium. Subsoil low to medium.	Flood or furrow	Liable to surface waterlogging and possibly also to subsurface waterlogging	Pasture Rootcrops Larger vegetables
7	Surface low to medium. Subsurface low to medium	Furrow or Sprinkler	As for Class (6) soil type	As for Class (6) soil type

Note: [1] Perhaps up to 1/3rd of this class, particularly around Tyabb and Somerville, may be superior to the rest of this class because of higher subsoil permeability.

[2] In the Dalmore region, fertile areas of friable clay are underlain by peaty material which provides good drainage to a depth of several feet.

Source: Interim Report on the Potential for the Utilization of Reconditioned Water From the South-eastern Purification Plant

Once the basic factors are evaluated with positive results, irrigation requirements for profitable crop production are determined on the basis of rainfall records, runoff, percolation and evaporation. Finally, the profitable irrigation requirements are compared with the availability of reconditioned wastewaters and the costs of the proposed system are determined.

In the case of the Melbourne and Metropolitan Board of Works Farm at Werribee, Australia, site preparation requires the mechanical plowing of the irrigation site to a depth of two feet and the construction of evenly graded leveed cells. Land drains are constructed in even patterns to collect effluents.

A buffer of about two miles is maintained between the farm and other land uses.

Methods and Rates of Application. At the Board Farm, two methods of land application prevail. Land filtration takes the form of permanent pasture irrigation at 18-day intervals during the high evaporation rate periods of the year from October to April. The average application rates are 4 inches per irrigation by surface methods. Grass filtration operates during periods of low evaporation between May and September. It involves heavy irrigation of densely grassed areas of up to 20,000 gallons per acre per day. As wastewaters have an average BOD of 400 ppm and an SS of 200 ppm, both aerobic and anaerobic conditions develop with the irrigation cell at different times in the process.

Land filtration requires from 180 to 250 acres per mgd and grass irrigation requires 48 acres per mgd.

Ground Covers. Ground covers are limited to grasses and pasturage by government regulation.

Land Application Performance

Agricultural production for many crops is greatly improved through the use of land application. In many cases, twofold increases in production are reported. The potential for crop product quality impairment may exist in the production of certain crops.

The experiences reported for a few countries are as follows:

a. Hungary

Resulting Soil Conditions. In Poland, tests on loose soil indicated that wastewater irrigation transmitted 92 percent of all its nitrogen, 86 percent of its phosphorus and 71 percent of its potassium to the soil. German studies indicated that wastewater irrigation had no harmful effects on soil composition or porosity. It was found, however, that pH generally increased as did the proportion of calcium and sodium. Soil composition generally improved. No deterioration in the physical structure of the soil or its tested chemical properties occurred.

At the Debrecen Experimental Sewage Irrigation Station at Debrecen, Hungary, domestic wastewaters were found to have between 490 to 980 mg/l of total organic material; total nitrogen was between 42 and 81 mg/l; potassium occurred between 42 and 63 mg/l; and phosphorus existed between 0.7 and 7 mg/l. Soil analysis indicated that humus, nitrogen and potassium increased. Only the phosphorus content of the soil decreased appreciably. Although total dissolved solids were high - between 1,011 and 1,285 mg/l - sodium ranged between 36 and 61 percent and magnesium ran between 21 and 46 percent, year-round irrigation did not cause significant alkaline ratios.

Table 93, Annual Nutrient Values Added by Wastewater Applications, indicates the nutrient values to the ground covers and soils on an annual basis.

Production. The agricultural production resulting from the use of domestic wastewater irrigation appears in Table 94, Produce Results of Plants Irrigated With Urban Sewage (Debrecen, Hungary). A comparison of this agricultural production with that of a site not irrigated with domestic wastewaters is shown in Table 95, Comparison of Production Results, with and without Urban Sewage Irrigation (Debrecen, Hungary). Significant increases in productivity resulted in all areas except for sugar beets which are intensively fertilized with manure in normal Hungarian farm operations.

TABLE 93
ANNUAL NUTRIENT VALUES ADDED BY WASTEWATER APPLICATIONS

Wastewater	Useful Nitrogen	P205	K20	Organic Material
Domestic	50-400 kq/kh	1-10 kq/kh	30-300 kq/kh	1,000-4,000 kq/kh
Fruit and vegetable canning	16-30 mg/l	1.2-11.9 mg/l	12-129 mg/l	1,000-1,200 mg/l
Sugar refining	30-60 mg/l	3-4 mg/l	110-140 mg/l	5,000 mg/l
Starch	43-99 mg/l	0.1-1.9 mg/l	16-20 mg/l	2,000-3,000 mg/l
Hemp	37-90 mg/l	6-37.5 mg/l	366-876 mg/l	1,600-4,370 mg/l

Source: Scientific Research Institute for Water Supply Economy

Only two negative quality impacts were realized, in addition to enhanced agricultural production. Hemp stalk crops were increased but the resulting fiber was coarsened and could only be used for low-grade purposes. Transplanted crops were found to have underdeveloped root structure due to the availability of irrigation water and could not be transplanted successfully.

b. Israel

Production. More than 100 systems exist in Israel and have, in general, produced excellent results in agricultural production. The yields from irrigated plots are significantly higher than those from plots irrigated with normal water, with an equivalent amount of chemical fertilizers alone.

c. Australia

Resulting Soil Conditions. Improvement to the native soils resulted from land application on the Werribee Farm. The degree of improvement is illustrated in Table 96.

Performance:. A summary of the Farm's wastewater quality enhancement performance appears in Table 96, Enhancement of Soil by Wastewater Application (Werribee Farm).

Production. In addition, the pasturage provided grazes 15,000 head of cattle through the year. Forty to fifty thousand sheep are fattened during spring and summer. This results in the sale of 5,000 cattle, 36,000 sheep and 250 bales of wool during the average year.

d. England

The West Hertfordshire Main Drainage Authority, located at Rickmansworth, about 20 miles north of London, England, serves an area of 210 square miles with a population of 550,000. A volume of 141,000 cubic meters (37 mgd) of wastewater each day, 80 percent of which is from domestic sources, is treated in a two-stage treatment facility. The Authority was organized in 1939, but the irrigation of digested sludge was not commenced until 1952. To avoid public reference to sewage, sewage-connected terms, and the connotation associated with the use of such terms, the digested sludge has been given the name of HYDIG. The effluent from the secondary treatment plant, having a quality better than 10/10 (Royal Commission standards: 15 ppm SS and 20 ppm BOD), is discharged into a river. The effluent at discharge into the river contains on the average 18 ppm of oxidized nitrogen (0.03 ppm ammonial) and 5 ppm of phosphorus.

The daily flow of 37 million gallons of wastewater produces about 90 million gallons per year of liquid digested sludge. The sludge has a solids content of about 3 percent, more or less, which is applied to the land, either by spreading from tank trucks as they roll across the fields, or by irrigation from pits or large stationary storage tanks located adjacent to the fields. Approximately 1,000 acres are owned by the Authority and used as experimental farmland, and the balance of the 6,000 acres is operated or owned by some 62 private farm units. The cost of transporting and applying the HYDIG is about $4 per 1,000 gallons which contrasts with the cost of

TABLE 94
PRODUCE RESULTS OF PLANTS IRRIGATED WITH URBAN SEWAGE AND THE AVERAGE SEWAGE QUANTITIES USED
(Debrecen, Hungary)

	Examined Year or Period	Type of Produce	Average Produce (q/ha)	Average Sewage Depth (mm)
Sugar beet	1961-67	root	363.24	392
Maize	1961-66	dry grain	58.50	368
Maize for silage	1961-67	green	346.19	290
Lucerne, 1-year-old	1961-64	hay	90.72	577
Lucerne, 2-year-old	1963-65	hay	120.29	309
Lucerne, 3-year-old	1964-66	hay	85.07	115
Red clover	1966	hay	99.25	399
Alexandrian clover	1966	hay	123.37	598
Papilionaceae mixture	1961	hay	111.50	201
Sudan grass (main sowing)	1962-66	hay	73.17	308
Sudan grass (after seed)	1963-65	hay	37.96	254
Vetch	1963-65	hay	38.09	83
Mixture of oats and vetches	1962	hay	49.52	248
Fodder pea	1963	grain	29.91	91
Broomcorn, white	1964	grain	8.62	268
Broomcorn, brown	1964-66	grain	24.93	598
Spring vetch (intercultural)	1967	grain	6.62	267
White mustard (intercultural)	1967	grain	2.45	38
Sunflower	1965	grain	14.87	490
Squash (for seed)	1966-67	seed	3.16	281
Castor bean	1963-64	seed	19.20	930
Solanum	1963-64	green	164.69	777
Digitalis	1967	green	16.37	281
Hemp	1961		83.77	340
Potato (industrial)	1965	tuber	119.80	275
Wheat (autumn)	1967	grain	29.35	87
Wheat (spring)	1967	grain	29.89	135

NOTE: q/ha = quintal/hectare – 220.46 lb/2.47 acre = 89.25 lb/ac

TABLE 95
COMPARISON OF PRODUCTION RESULTS WITH AND WITHOUT URBAN SEWAGE IRRIGATION
(Debrecen, Hungary)

Plant	The Examined Year or Period	Average Sewage Depth mm	Type of Produce	Irrigated	Non-irrigated
				Average Produce (q/ha)	
Sugar beet	1961-67	392	root	363.24	363.00
Corn	1961-66	368	grain	58.50	22.49
Maize for silage	1961-67	290	green	346.19	217.25
Lucerne 1-3 years old	1961-66	399	hay	99.25	36.58
Sunflower	1965	490	grain	14.87	4.17
Potato (industrial)	1965	275	tuber	119.80	59.73

Source: Utilization of Urban Sewage—Vermes, Hungary

TABLE 96
ENHANCEMENT OF SOIL BY WASTEWATER APPLICATION
(Werribee Farm)

	Native Soil	Before Irrigation	After Irrigation	
			12 yrs.	26 yrs.
Nitrogen	1,400 ppm	1,200	2,620	500
Phosphoric Acid	920 ppm	450	1,700	2,500
Potash	3,230 ppm	1,540	8,010	10,920
Lime	2,700 ppm	600	3,200	3,900
Chlorine	190 ppm	420	260	210

TABLE 97
ENHANCEMENT OF WASTEWATER QUALITY FROM LAND APPLICATION
(Werribee Farm, Australia)

Method of Treatment	Quantity Treated MG	BOD	SS	Detergent	Nitrogen Total	Phosphorous Total	E. Coli
Land Filtration	9,020	98.0	97	80	90	80	98.0
Grass Filtration	12,886	96.0	95	50	60	35	99.5
Lagoons	21,049	94.0	87	30	40	30	99.8
Total	42,955	95.5	92	50	60	45	99.0

Source: Tables from Waste into Wealth and Post Graduate Course in pH Engineering ocean dumping of about $9 per 1,000 gallons. The disadvantages of tank truck operation are more than offset by the savings that result from having neither investment in 5,000 acres of privately owned farmland nor farm operating expenses on this land.

The irrigation is done on gravel soils that are fairly firm and easily drained. The crops grown include grass, forage crops, English black beans, grains, potatoes and other root crops. There has been no buildup of toxic salts, no cattle disease, no objectionable odors, no fly problem, and no community objections. The public health officers are satisfied that the irrigation procedure is not a threat to public health. There have been some individual complaints, but the majority of these have involved the use of the highways by the large tank trucks. The principal problem appears to be the potential long-term harmful effects of certain undesirable trace metals in the sludge. The toxic metals most frequently found are zinc, copper and nickel.

Research work by the British Ministry of Agriculture has established that nickel is four times more toxic to plant life than copper which is, itself, twice as toxic as zinc. This discovery made it possible to simplify the composite effect of these metals in any particular sample of sewage by expressing the effect as "zinc-equivalent." The Authority has set for itself these tentative guidelines pending further research work. If, in a sample of virgin soil which is free from metal traces, no more than 250 ppm of zinc-equivalent is allowed to build up in the top soil, then there is no risk of damage to plant life due to the metals. Unfortunately, the buildup appears to be cumulative. The Authority has selected a 30-year period for the application of sludge to a particular piece of land, and is currently limiting the annual dressing to no more than 1/30 of the 250 ppm arbitrary maximum. Research is also being done to determine whether or not over a prolonged period the minute traces of lead, cadmium, arsenic and mercury will have any deleterious effect upon plant life. Chromium as a chromium salt in sewage has been found not to be toxic unless it is present in very high concentrations. Similarly, boron (from detergents) was found to be nontoxic, except in high concentrations. Boron, unlike the other metal traces, quickly leaches down into the subsoil.

The other principal and tentative injunction which the British Ministry of Agriculture rendered related to the avoidance of an acidic soil condition. It has been found that when the soil becomes more acid than pH 6.5, it seems to accelerate the toxic effects of certain trace metals on the plant life. As a general precaution, livestock should not be allowed to graze fields to which sewage has recently been applied until after rain has washed the edible plant sections clean. Rain will reduce the potential hazard to livestock from ingestion of lead and mercury which may have been deposited on the plant surfaces.

Public Health

Another situation exists in the area of public health. An appropriate degree of sensitivity exists within this area because of ever-present hazards that may be unleashed. A strong example exists in the case of Israel.[15] Investigation during the 1970 cholera epidemic in that country resulted in evidence that cholera was being transmitted by the consumption of vegetables irrigated with wastewater. The result was an immediate administrative response forbidding the use of land application for the irrigation of any food crops - whether cooked or raw.

Investigations on the part of the Central Public Health Engineering Research Institute of Nagpur, India, disclosed a higher incidence of selected diseases, skin condition and parasites among sewage farm workers than other occupational workers. Many of the diseases are endemic to vast parts of India. A summary of this investigation is contained in Exhibit VI.

The hazards to public health in areas where diseases that are waterborne or transmitted by water-related vectors occur endemically produce significant problems of site selection, design, land application management, regulation and control. Too often, health regulations do not reflect these needs due to the limitation of what is really known locally about the land application process. While bacteriological examination may show no relative difference between the bacterial levels on plants normally grown and those irrigated by the application process, the surface of the application site bears a significantly higher bacterial level than would a normal site. This fact dictates special control in the irrigation of crop types or special precautions in crop harvesting.

A few examples of some of the existing health regulations follow.

a. Hungary

An extract of a few of the applicable regulations from Hungary follows. It should be noted that these regulations are incomplete in the form presented. (Extracted from the five Hungarian reports.)

1. Wastewater Treatment – Before irrigation, domestic sewage shall be treated in a settling tank for 1-1/2 to 2 hours at a 2 mm/sec flow velocity.

2. Application Site Regulations – Irrigation fields shall be located 300 meters distant from the closest residential districts and surrounded by a forested buffer. Groundwater shall be at least 1.5 meters below the ground surface.

3. Industrial Wastewaters – May be used for crop irrigation with no restriction as to crop type.

4. Domestic Wastewater – Cannot be used for the irrigation of garden products for human consumption. Domestic wastewater may be used for irrigating timber trees, forests, meadows and pastures (except during the growing season) and plowed lands before sowing without restriction. Domestic wastewater irrigation must be terminated:

   a. Prior to the onset of blooming in the case of grain crops and eatable potatoes
   b. Four weeks in the case of industrial potato, fodder crops, sugar beets, oil and fiber plants
   c. Two weeks before harvesting and grazing in the case of hay, perennial papilionaceous meadows and pasture during the months of July and August and three weeks during the remainder of the year

5. Employee Health Protection – Employees should be provided with:

   a. Good quality water
   b. Vaccination
   c. Periodic medical control
   d. Protective clothing

6. Timber Crops – May be irrigated without restriction.

7. Separate regulations exist for orchard irrigation.

b. Israel

Exhibit VII contains the health regulations which have been administratively amended to preclude the land application of crops for human consumption.

c. Australia

Exhibit VIII, Land Application Regulations in Australia, contains the health regulations and analysis relating to the problems of land application regulation in Australia as supplied by the Interim Report On the Potential for the Utilization of Reconditioned Water from the South-Eastern Purification Plant, prepared by Melbourne and Metropolitan Board of Works and State Rivers and Water Supply Commission of Victoria, Australia.

Case Studies

Finally, to supplement the study project's investigation of wastewater land application in other countries, the following case studies are presented. These case studies provide a clear sense of the form and character of some of the systems used in other parts of the world and some of the experimental efforts currently under way.

Mexico City, D. F., Mexico

1. Basic Data. Mexico City has an elevation of approximately 7,500 feet in a valley completely surrounded by high mountains. Population of the City of Mexico

City is approximately 8 million and an additional 2 million people live immediately adjacent to the Federal District boundaries.

In 1902, a canal and tunnel system was dug to convey wastes approximately 70 kilometers (44 miles) north to the Tula area.

The City of Mexico City is sinking 8 to 10 centimeters per year and it is now necessary to pump into the canal system.

The city is served by a combined sewer system which has a dry-weather flow of approximately 25 cubic meters per second (570 mgd). Wet-weather flows reach 2,000 cubic meters per second (4,560 mgd). The potable water system for the area is from a well field some distance away. Approximately 35 cubic meters per second (800 mgd) are supplied to the city.

Due to the increases in storm runoff and possibility of flooding the central part of the city at any time due to pump failures or excessive storm flow, a deep tunnel system is being constructed at a cost of 4 billion pesos. ($320,000,000) The annual cost of disposal will be reduced by the pumping costs now required, an amount equal to amortization of about one-half of the construction cost. The tunnel is from 150 to 750 feet deep with 37 shafts. The tunnel is to be completed in March 1974, at which time approximately 70 percent of the dry-weather flow of the canal will be diverted to the tunnel. The tunnel is being designed for a storm flow of 200 cubic meters per second.

The tunnel is 6-1/2 meters (26 ft.) in diameter and has a design velocity of 1 meter per second for dry-weather flow and 6 meters per second for storm flows. The Mexico City area has 700 millimeters (27 inches) of rainfall per year.

2. Urban Use. In addition to the untreated flow, 5 cubic meters per second are treated in five secondary treatment plants within the City, which have a capacity of 7.5 cubic meters per second. This flow is used for irrigation of parks, playgrounds and other large public areas, as well as for the filling of lakes in parks and for fountains. Solids from the treatment plants are discharged to the untreated flow. The flow used within the City is chlorinated prior to application and is used in Chapultepec Park, the University of Mexico and Olympic sports arena and parks.

The treatment plants are operated only during the dry season – November through May. The Federal District has determined its costs for treating the effluent for watering within the city at 25 centavos per cubic meter (16 cents per 1,000 gal.).

3. Crop Irrigation. The balance of the sewage, approximately 20 cubic meters per second, is discharged to the irrigation canal. It is estimated that approximately 95 percent of this flow reaches the land; the balance is lost to evaporation and infiltration.

The irrigation area was formed as a cooperative; the government owns the land but has given it to farmers as long as the land is used for farming. In the Tula Hidalgo approximately 47,000 hectares (111,746 acres) are being irrigated at this time and plans exist for a Phase 2 of 27,000 hectares to be irrigated, and for Phase 3, an additional 13,000 hectares to be irrigated. In the Tula Hidalgo, 24,837 hectares are farmed by 20,295 Ejidos (heads of families). The balance of the 20,369 hectares are owned by 8,278 persons.

The area is served by the Tepeji River and flow not used for irrigation eventually flows to Tampico. There are three storage reservoirs for irrigation water, totaling 301 million cubic meters. During the dry season, sewage and irrigation water are jointly used, and during the wet weather, natural river water is stored for use during the dry season. On an annual basis, approximately 700 million cubic meters (185,000 mg) of sewage are used and 200 million cubic meters (54,000 mg) of irrigation water are used. In 1971, 672,654,000 cubic meters were used on the 47,000 hectares.

Upon the 47,000 hectares, 1,476,749 tons of food products were raised, with a value of 333,783,710 pesos ($26,701,000). Crops are grown by farmers in response to market demand. They have not found sewage to be toxic to any natural crops. Only one crop per year is produced, with the exception of alfalfa where 10 cuttings are made. Crops include alfalfa, corn, wheat, tomatoes, chiles, flowers and other truck garden crops. Table 98, Summary of Agriculture Production 1971-72, 03 Irrigation District–Tula Hidalgo, presents the tons of crops raised.

The Tula Hidalgo is operated by the Federal Department of Agriculture and the costs of the operations are paid by the Ejidos on the following basis: 30 pesos ($2.40) per hectare for 40 percent of the land farthest from the head of the district and 20 pesos ($1.60) per hectare for the remaining 60 percent by individual holdings per time of irrigation. Each irrigation is 20 centimeters (7.8 inches) of water on the land.

The farmers have found that the alfalfa commands a premium and also is heavier than normal due to the use of sewage.

Drinking water for the 100,000 residents of the area is from springs above the Hidalgo. Land adjacent to the project is worth 500 pesos per hectare ($17/acre). The irrigated land is worth 30,000 to 50,000 ($100-$160 per acre) pesos per hectare. The irrigation area receives 400 cm (16 inches) per year of rainfall. The Hidalgo has excellent records indicating the amount of return flow to the river by using gauges on the river above and below the District.

Observations were not available as to the changes in the quality of the flow at the point of distribution, as compared to inland. It is apparent that the canal acts as one long oxidation ditch and that slime growths and such along the canal must be oxidizing part of the material. ABS is a problem inasmuch as Mexico has not switched to soft detergents. Foaming was noticed at the canal and gate structures. Odors along the canal are not noticeable. The area which is farmed has few homes adjacent to the farm land. Most people live in the villages where conveniences are available. All work is done by hand. No farm equipment was seen.

Melbourne and Metropolitan Board of Works Sewage Farm, Werribee, Australia[16]

1. Basic Data. The Board of Works Farm occupies 42 square miles of formerly barren, arid, windswept plain south of the Werribee River and adjacent to Port Phillip Bay. Originating in 1892, the Board of Works Farm has grown to serve a population of 1,806,000 people and an average flow of 96 mgd to 250 mgd during rainy periods. A total of 10,378 acres of the farm is employed for irrigated pasture, 3,393 acres are used for lagooning of wastewaters, and 3,472 acres find use in grass filtration. The general criteria for site selection suggested by the experience gained at the Board of Works Farm involve:

a. An adequate area of land with suitable soils and contours
b. Low rainfall
c. High evaporation
d. Isolation from centers of population appropriate to the type of treatment.
e. Isolation from points of groundwater withdrawal

2. Soils and Site Preparation. Soils generally include delta alluviums in some places and shallow loams covering a dense layer of clay in others. Soils are generally mechanically plowed to a depth of two feet and the area is broken into cells, even graded to assure the even distribution of wastewater. Land drains are constructed in regular patterns to collect effluents of the land application process.

3. Operations. Three modes of treatment are employed on the basis of season and flow These are presedimented or raw wastewaters, depending upon their location in the older or newer parts of the farm:

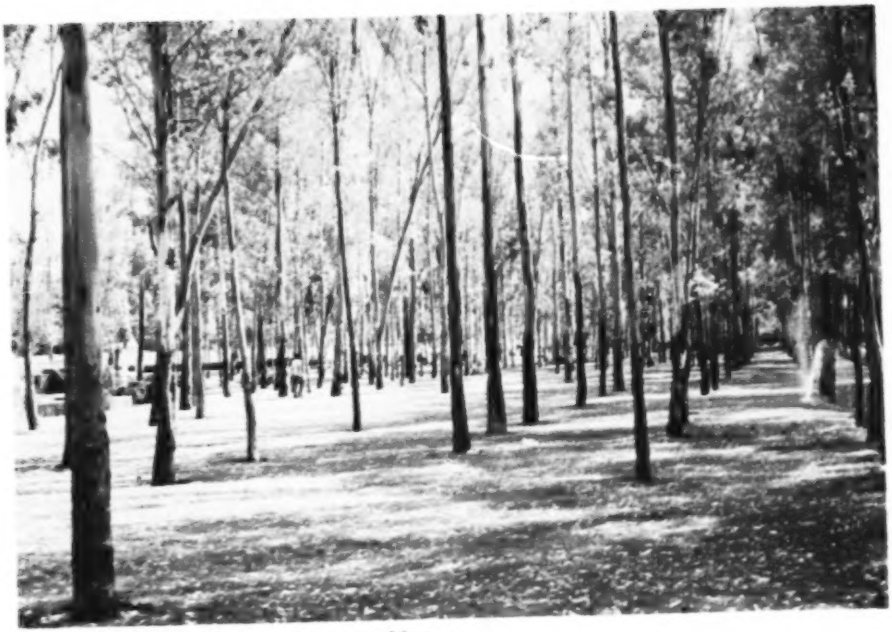
a. Land filtration: takes the form of permanent pasture irrigation at 18-day intervals during the high evaporation periods of the year from October to April. The average application rate is 4 inches per irrigation. Effluents are clear, colorless and odorless and are collected in the land drains and discharged to Port Phillip Bay. One acre is found to serve 100 persons or 5,000 gpd.
b. Grass filtration operations occur during the periods of low evaporation between May and September. This involves the heavy irrigation of densely grassed areas of up to 20,000 gallons per acre per day with BOD of 400 ppm and SS of 200 ppm. Both anaerobic and aerobic conditions develop within the irrigated cell at different times in the process. Effluents are light brown in color due to the staining from the vegetation and are also

TABLE 98
SUMMARY OF AGRICULTURE PRODUCTION
1971-1972
03 IRRIGATION DISTRICT – TULA HIDALGO

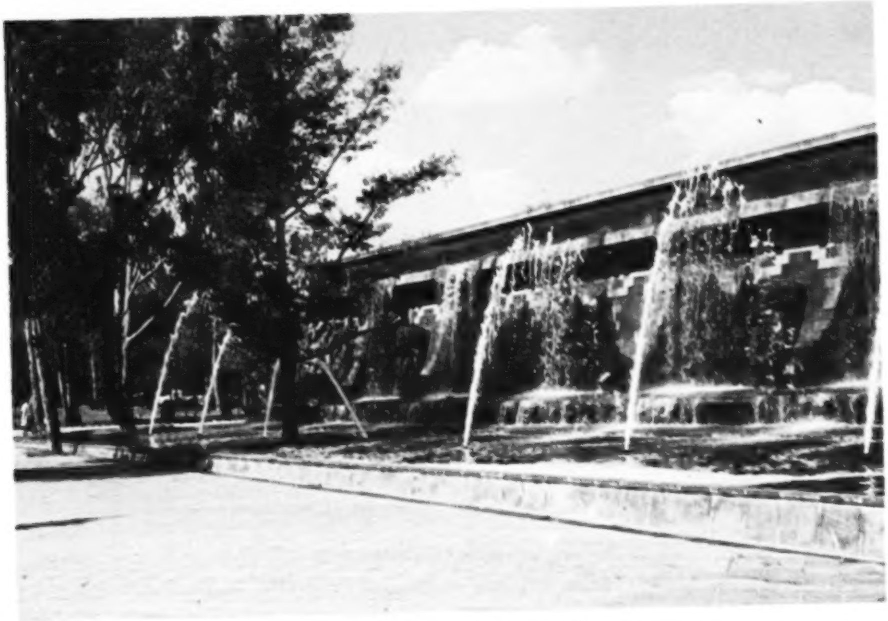
Crop	Crop	Hectares	Metric Tons
Alfalfa Verde	Alfalfa	12,396.40	1,181,376.920
Ajo	Garlic	94.50	258.456
Arvejon	Peas (large)	12.89	20.820
Avena Verde	Green Oats	2,998.75	54,426.714
Calabacita	Squash (small)	674.33	7,282.764
Cebada Grano	Barley Grain	1,865.43	3,645.410
Cebada Pago	Barley (forage)		4,059.874
Cebolla	Onion	23.79	168.909
Cilantro (semilla)	Parsley Seed	3.53	4.589
Col	Cabbage	27.95	501.843
Chicharo	Peas	1.00	7.900
Chiles Verde	Green Hot Peppers	768.80	8,231.350
Flores	Flowers	10.41	
Frijol Grano	Navy Beans	1,259.02	1,563.870
Frijol Ejote	Am. String Beans	58.30	151.580
Espinaca	Spinach	0.82	9.020
Frutales	Fruit Trees	25.08	213.180
Girasol	Sunflower	37.19	230.578
Haba	Lima Beans	95.84	1,990.070
Jitomate	Am. Tomato	1,554.65	49,437.870
Lechuga	Lettuce	74.47	1,457.764
Maiz Grano	Corn (kernels)	17,053.60	70,260.525
Maiz Rastrojo	Corn (forage)		65,179.023
Maiz Verde	Corn (sweet)	101.20	7,084.000
Nabo Forraje	Forage Turnips	112.37	1,011.330
Melon	Melon	1.00	7.100
Pepino	Cucumber	34.74	166.752
Pradera	Meadow Grass	12.80	2,080.000
Tomate	Tomato	216.90	2,051.706
Trigo Grano	Wheat Grain	7,293.79	13,865.494
Sandia	Watermellon	0.40	3.960
		46,809.95	1,476,749.371
		Acres	**U.S. Tons**
		115,620.65	1,624,424.30

Note: 1 metric ton = 1.1 (U.S.) tons
1 (U.S.) ton = 0.907 metric tons
1 hectare = 2.47 acres

Note: The crop hectares listed are more than the hectares of land available since a second crop in some instances has been produced on the same land.

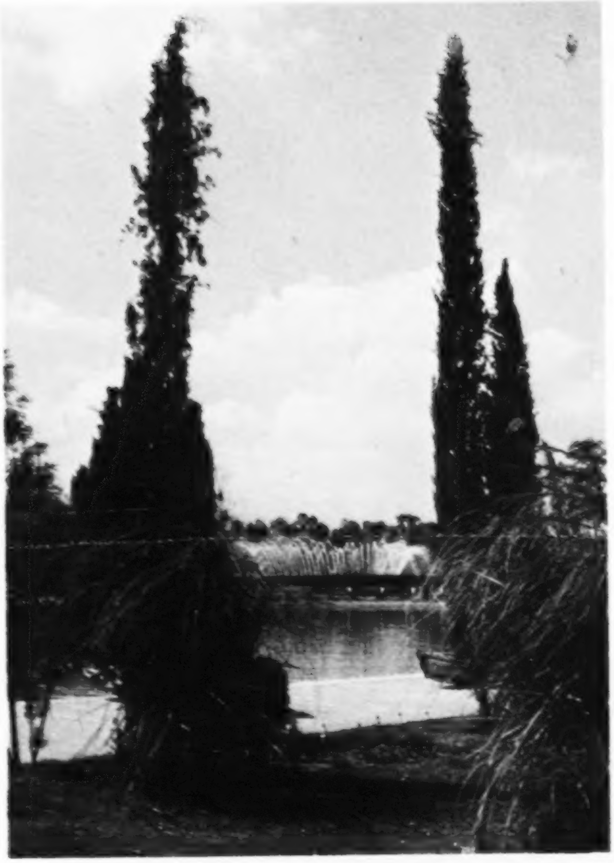


a. Chapultepec Park, watering of lawns



b. Chapultepec Park, decorative lakes and fountains

FIGURE 11
USE OF TREATED EFFLUENT, MEXICO CITY, D.F.

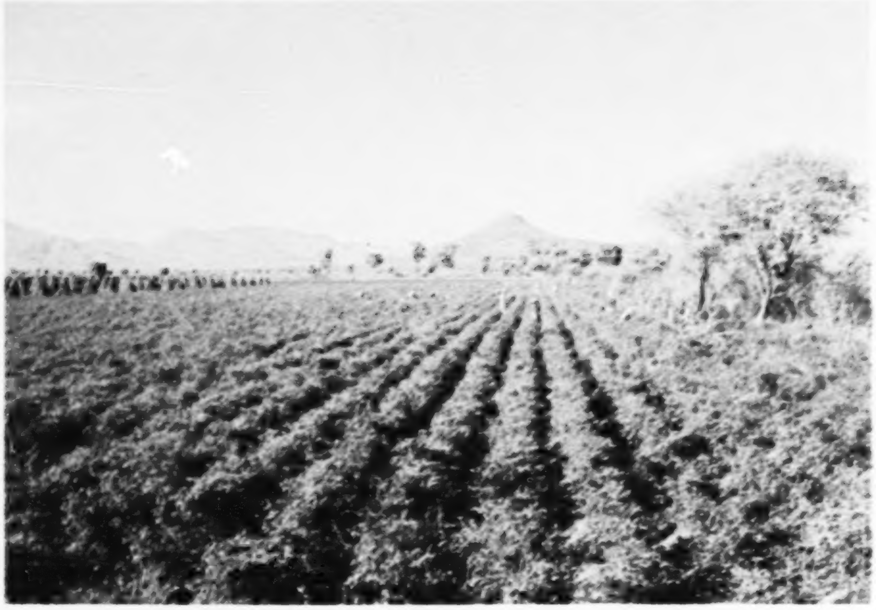


c. Chapultepec Park, secondary effluent used for lakes used for boating

FIGURE 11
USE OF TREATED EFFLUENT, MEXICO CITY , D. F.

a. Alfalfa, irrigated with raw sewage, 10 cuttings per year

FIGURE 12
IRRIGATION OF FARMLAND, TULA HIDALGO, MEXICO



b. Tomatoes irrigated with raw sewage

c. Distribution canal for raw sewage

FIGURE 12
IRRIGATION OF FARMLAND, TULA HIDALGO, MEXICO

collected and discharged to the Bay.

c. Lagoons store and treat daily peaks and wet-weather flows and are constructed in series with even controls between. Thus, the first lagoons in series operate anaerobically with subsequent lagoons inevitably functioning aerobically. First pond loadings amount to from 550 to 675 lbs. of BOD per acre per day. The overall loading to the lagooning system ranges from 60 to 100 lbs. of BOD per acre per day. The lagoon systems exist at a lower elevation than the land and grass filtration systems and thus do not provide storage to serve these areas.

Prior treatment generally amounts to preliminary settling. Only 20 percent of the flows reach the land without some treatment. Sludges from these processes and those collected from lagoons are digested in open lagoons, land-dried, and subsequently used as a soil conditioner.

Application methods used involve surface flooding, although other methods could be used as well, depending on the degree of treatment provided the wastewater. Land filtration at the Board of Works Farm requires from 180 to 250 acres per mgd, and grass irrigation requires 48 acres per mgd. Groundwater has high chloride content (2,000 - 3,000 ppm) and appears to provide no interference problems. A two-mile-wide buffer zone is maintained to isolate the Farm from adjacent developing areas.

4. System Performance. A summary of the farm's wastewater quality enhancement performance appears in Table 97, Enhancement of Wastewater Quality from Land Application (Werribee Farm). The cost of this method of treatment is $0.045 per 1,000 gallons (Australia).

In addition, the pasturage provided grazes 15,000 head of cattle through the year. Forty to fifty thousand sheep are fattened during spring and summer. This results in the sale of up to 5,000 cattle and 36,000 sheep and 250 bales of wool per year.

5. Health Restrictions. The only health restrictions are those imposed on the sale of cattle and sheep for slaughter purposes – primarily for control of tapeworm in cattle. The condemnation rate of cattle carcasses – 0.02 percent – is the same as for the remainder of the state. No higher incidence of disease among farm employees has been found as a result of their employment.

Debrecen Experimental Sewage Irrigation Station, Debrecen, Hungary[17]

1. Basic Data. The Debrecen Experimental Sewage Irrigation Station occupies approximately 35 acres adjacent to the city wastewater sedimentaiton plant. The station began operations in 1959 in a climate with an average annual precipitation of 599 mm (23.6 inches), 2,000 hours of sunlight per year and an average annual temperature of 10.2°C (50.4°F).

2. Soils and Site Preparation. The soils encountered were variable but generally sandy loams of good permeability. Generally they were found to have low salt contents and were moderately well supplied with nutrients. The groundwater table occurred at from 140 to 150 cm (approximately 5 ft). Groundwater had a high salt content and was of a carbonate-chloride-sulfate makeup. The site was broken into roughly 0.57 test plots (1.4 acres). Some of these plots functioned as field crop sites and others as porous catch plots for surplus wastewater disposal.

3. Operations. The wastewaters employed apparently were subject to sedimentation for pretreatment. Wastewaters were applied by spray irrigation and surface application during subsequent years. Irrigation took place primarily during cultivation originally and subsequently occurred during crop growth as well. Irrigation wastewaters were found to have a total organic content of from 490 to 980 mg/l, total nitrogen at 42 to 81 mg/l, potassium at 42 to 63 mg/l and phosphorus at 0.7 to 7 mg/l. The use of these wastewaters resulted in the application of the following to the crops on an annual basis.

N	50-400 kg/kh	470-3,800 lb/acre
K_2O	30-300 kg/kh	280-2,800 lb/acre
P_2O_5	1-10 kg/kh	10-100 lb/acre
Organic Matter	1,000-4,000 kg/kh	9,500-38,000 lb/acre

4. *Performance.* As the experimental station project was primarily concerned with the agricultural impact of wastewater irrigation, the performance was measured in terms of agricultural impact. The crop yields of the station, in comparison to the yield at the Gyozelem Farm near the station, resulted in the following:

	Debrecen Station	**Gyozelen Farm**
Sugar beets	363.24 q/ha	365.0 q/ha
Dry grain maize	58.5 q/ha	22.49 q/ha
Fodder maize	346.19 q/ha	217/25 q/ha
Alfalfa	99.25 q/ha	46/58 q/ha
Sunflower seed	14.87 q/ha	4.17 q/ha
Industrial potatoes	119.8 q/ha	59.3 q/ha

The foregoing suggests the yield-increase effect of wastewater irrigation, as compared to normal practices. Only two crops experimentally irrigated were accompanied by deteriorated quality – hemp stalk and summer cuttings. The former developed fiber too coarse for industrial use and the latter could not be transplanted as required because of underdeveloped root structures.

EXHIBIT VI
HEALTH STUDY
CENTRAL PUBLIC HEALTH ENGINEERING RESEARCH INSTITUTE, NAGPUR, INDIA

The Central Public Health Engineering Research Institute, Nagpur, India, has published the following study: CPHERI's present study has included in its survey a thorough clinical examination (including hemoglobin estimation) of each worker and the stool sample examination using different concentration techniques for detailed information about multiplicity of infection.

Diseases Observed at Time of Study	**Test Group (%)**	**Control Group (%)**
Gastrointestinal (dysentery, enteritis, etc.)	45.6	13.0
Respiratory (dyspnoea, bronchitis, etc.)	19.6	4.3
Anaemia	50.3	23.6
Skin conditions (pigmentation, rashes, etc.)	22.3	4.0

Stool samples were examined for *Ancylostoma duodenale* (hookworm), *Ascaris lumbricoides* (roundworm), *Trichuris trichura* (whipworm), *Enterobius vermicularis* (pinworm), *Hymenolepis nana* (dwarf tapeworm), *Entomeoba hystolytica,* Ent. coli and *Giardia intestinalis* and the results were as below:

	Test Group		**Control Group**	
CPERI Study on Three Sewage Farms	**No.**	**%**	**No.**	**%**
Total examined	360		306	
Total positive	303	84.0	179	59.0
Positive for hookworm	231	64.1	123	40.1
Positive for roundworm	245	68.0	159	52.0
Infection with two or more parasites	156	43.3	44	14.4
Dr. Kabir's Study on Madurai Sewage Farm				
Total examined	663		2,644	
Total positive	520	78.4	512	19.3
Dr. Patel's Study on Two Village Farms near Baroda				
Total examined	152		479	
Total positive	114	75.0	287	60.0

As can be seen from the table, the incidence and multiplicity of infection are far more in the sewage farm population than in the control. Regarding the multiplicity of infection in the control population, it was confined to the combination of two parasites, whereas in the sewage farm group it ranges from two to five parasites. The significantly high rate of multiplicity and incidence of infection in the sewage farm group illustrates the hazards in the handling of raw sewage for a prolonged time.

Exhibit VII
Health Regulations, Israel

1. *Definitions*
   In these conditions, the following terms shall have the meaning which appears below;
   Road – A road liable to be used by motor vehicles;
   Spray irrigation – Irrigation by spraying in which there is no direct contact between the liquid sprayed and the plants or trees irrigated;
   Director – The Director-General of the Ministry of Health or any official authorized by him in writing to carry out these conditions under the Trades and Industries Ordinance;
   Irrigation – Includes spray irrigation
   Secondary sewage treatment plant – A sewage treatment plant based on biological treatment processes;
   Effluent – Sewage purified by an aerobic secondary sewage treatment plant approved by the Director and operated in such a manner as to be satisfactory to him;
   Sewage – All liquid wastes containing suspended and dissolved material, human, animal or vegetable matter as well as chemicals in solution.
2. *Irrigation with sewage*
   Sewage is not to be used for irrigation.
3. *Conditions under which irrigation with effluent is allowed*
   Irrigation with effluent is allowed on the following crops only:
   (1) Water-melons, nuts, ground-nuts, sweet potatoes, okra, bananas, citrus fruit, olives, eggplant, melons, trees for landscaping, flowers, marrows, date trees and potatoes.
   (2) Crops for industrial use and not used for human consumption.
   (3) Nursery trees.
   (4) Fodder crops for harvesting and not for grazing.
   (5) Fodder crops for grazing of cows or sheep on condition that the animals do not graze on the irrigated area until it is completely dry.
4. *Deciduous fruit trees*
   In spite of the conditions in paragraph 3 above, the Director may allow low-level spray irrigation of deciduous fruit trees with effluent if the following three conditions are fulfilled to his complete satisfaction:
   (1) The spray irrigation be so carried out as to prevent effluent from coming in contact with fruit.
   (2) That spray irrigation ceases two weeks before fruit is harvested.
   (3) That the wind-fall not be marketed.
5. *Irrigation of lawns with effluent*
   Effluent shall not be used to irrigate lawns unless the following conditions are met:
   (1) The sewage to be used for irrigation be treated in oxidation ponds, in series, having a minimum detention period of 20 days or treated in a biological treatment plant and disinfected with chlorine.
   (2) After being treated as above, the sewage shall meet the bacteriological standard determined by the Director.*
   (3) The irrigation be carried out only when the lawns are closed to the public.
6. *Precautions to be taken before irrigation*
   Before irrigation with effluent is carried out, the following precautins shall be taken:
   (1) The areas to be irrigated shall be clearly designatee with signs warning in clear and visible letters that sewage irrigation is being carried out.
   (2) The pipe network for sewage irrigation be completely disconnected from the regular water supply network

(3) All necessary steps be taken to prevent mosquito or fly breeding in the area to be irrigated.
(4) All necessary steps to be taken to prevent the dissemination of odours which may reach residential areas, or other areas in which the public is likely to be present.
(5) No spray irrigation with effluent to be carried out within a distance of 200 m from a residential area or 50 m from a road.

7. *Ridge and furrow irrigation*

Ridge and furrow irrigation with effluent may be carried out if the distance to residential areas is greater than 100 m and the distance to roads is greater than 25 m.

8. *The use of effluents in fish ponds*

Effluents should not be used for breeding fish except under the following conditions:

(1) Effluent shall not be used in ponds for storing fish before marketing or in tanks used for their transport.
(2) Should snails be found, the owner or operator of the fish pond shall notify the nearest Health Office.
(3) In the case of snails which serve as vectors of schistosomiasis being found in the pond, the owner or operator shall carry out all instructions given by the Director including the drying out of the pond.

Director General **Dr. R. Gjebin**
State of Israel
Ministry of Health

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*Proposed standard: Coliform MPN's of 100/100 ml or less in four out of five samples

EXHIBIT VIII
LAND APPLICATION REGULATIONS IN AUSTRALIA

8.4 Criteria in Victoria

The re-use of wastewater for agriculture in Victoria is limited by the provisions of the Health Act 1958 (No. 6270) and certain Regulations made thereunder.

8.41 Use of Disposal Areas

Under the "Night Soil and Sewage (Contamination of Land) Regulations 1967," the sale of vegetables and fruit grown on land used for depositing and spreading night soil or sewage is forbidden. Fodder crops grown on such land cannot be used for feeding cattle and pigs - except by the Sewerage Authority concerned. A period of six months must elapse after the last deposit of night soil or sewage before land may be used for crops or grazing. There are no restrictions imposed on the grazing and sale of sheep, but the higher rainfall in certain parts of Victoria limit grazing of sheep for other reasons. However, there are severe restrictions imposed on the grazing and sale of cattle and pigs. No owner or occupier (other than a Sewerage Authority) of any land used for depositing or spreading night soil or sewage may allow cattle or pigs to be upon that land (s83 of Act). Sewerage Authorities are permitted to graze cattle and pigs on land used for this purpose, but they must not allow them to be removed from that land (even to the sewerage farm of another Authority), except when used for immediate killing for some purpose other than human consumption, or for killing at a Melbourne export abbatoir. They must be segregated from other cattle at all times, and when killed at an abbatoir are subject to a control and inspection system prescribed in the Regulations which are specifically framed for the detection and reporting of cysticercus bovis (beef measles). The carcasses which pass inspection may be used for the home market but may not be exported.

These provisions do not apply where night soil or sewage has been treated to a "prescribed standard" which, as defined by the Regulations, requires that the treated night soil and sewage should not contain eggs of taenia saginata or taenia solium which are capable of development. Night soil only is deemed (by Regulation) to meet the prescribed standard if subjected throughout its mass to a temperature of 212°F for not less than 10 minutes.

In connection with this prescribed standard, the writers understand that there is no simple and reliable method of detecting and monitoring the presence or absence of viable eggs of taenia saginata or taenia solium.

In the above Act there is no definition of sewage or wastewater; also there is no differentiation between untreated wastewater and highly purified wastewater.

8.42 Stream Pollution

In comparison with the above provisions, the "Stream Pollution Regulations 1943" (Health Act) prescribe the standards for the quality of an effluent water from a purification plant at the point of discharge into a stream.

These regulations require that, irrespective of stream flow (or lack of it), no sample of effluent water discharged shall contain more than 20 mg/l BOD nor contain more than 30 mg/l suspended solids. A further prescription is that, where a stream is used as a source of water supply, no 50 cc sample of effluent water shall contain any pathogenic organisms or bacillus coli communis (in practice usually taken as Escherichia Coli, Type 1). These are well established and readily performed tests.

8.43 General Remarks

A study of the requirements of the Health Act and Regulations thereunder, together with experience in their application to the disposal of effluent water, reveals some confusion and inconsistency with regard to the various provisions.

For example, it would appear that the object of the above legislation regarding contamination of land by night soil and wastewater is to prevent the transmission of pathogenic organisms (both bacteria and viruses). However, the only requirement preventing the free use of reconditioned water for irrigation of pastures is to prove that it does not contain the eggs of taenia saginata or taenia solium capable of development. On the other hand, the Stream Pollution Regulations, although requiring the discharged effluent water to contain no pathogenic organisms, make no specific reference to the eggs of taenia saginata or taenia solium, even though the stream may be used almost immediately for watering cattle or the irrigation of pastures, fruit or vegetables, etc.

While there are no reasonably simple tests for the detection of viruses, none of the legislative requirements could be regarded as ensuring the absence of virus contamination.

The concern exhibited by our Commission of Public Health for the well-being of the population is fully appreciated and commended. However, the time is fast approaching when Victoria will not be able to afford the wastage of reconditioned water, and it is suggested that the time has come to review existing standards and procedures for detecting and monitoring the presence or absence of harmful organisms in water supply and in effluent waters.

Source: pp 44-46, A.W. Bird, J.D. Lang – Interim Report on the Potential for the Utilization of Reconditioned Water from the South-Eastern Purification Plant, Melbourne and Metropolitan Board of Works and State Rivers and Water Supply Commission, Victoria, Australia.

SECTION VI

SUGGESTIONS FOR IMPLEMENTATION OF LAND APPLICATION SYSTEMS

Land application of wastewater effluents poses many problems, in the same way that any other engineering or scientific project does. The factors involved in this alternative method of wastewater management may be as complex as those involved in so-called conventional methods of treatment of sewage and industrial wastes and discharge of effluents into surface water sources.

Before decision is reached on the choice of land application as an alternative to a conventional wastewater management system, full study and careful evaluation must be made of these special problems, covering factors of engineering, economics, agronomy, social and demographic impacts and public health effects.

While clear-cut guidelines for implementation of land application systems are not always defined in terms of design, construction, operation, control and costs parameters, certain facts and criteria were deduced from the field of investigations, other surveys and studies of existing principles and practices in the U.S. and foreign countries, and the investigations carried out by other researchers.

While some numerical design and decision data are quoted, it must be made clear that each proposed installation is specifically unique due to local factors. This makes it necessary to evaluate all aspects of each project before decision can be made to adopt this wastewater management technique.

In preparation of these suggestions, an effort has been made to draw upon the bibliographic search and other sources, in addition to the data disclosed by the various phases of the current study.

Climate

Climate may have a great bearing on any decision to adopt land application practices and on the performance of this system.

In arid zones, wastewaters may be needed to augment insufficient natural precipitation for watering crops.

In areas with long growing seasons and absence of intense freezing climate, land application can be practiced year-round without need for holding wastewaters for long periods, or choosing means of irrigation which are not seriously affected by icing conditions.

In humid zones, evapotranspiration of moisture into the atmosphere will be inhibited. In wet areas, groundwater levels may not require augmentation.

In areas with prolonged drought, direct discharge of wastewater effluents to surface water sources may be needed to balance the water resources cycle and stabilize streamflows.

In hot summer zones, creation of septic conditions and consequent dissemination of irrigation-induced odors and insect breeding in ponded land areas may become a problem.

In sections where year-round recreation, such as golfing, is possible, the need for wastewater for irrigation and for creation of inland lake waters may become a factor in choosing land application in lieu of discharge of effluents into surface streams.

In all cases, weather conditions will affect the rate of application of wastewaters to land areas and the assimilation capabilities of soil.

Thus, decision-making, design and operation of land application systems will be guided and influenced by climatic conditions.

Results of the current study indicate that most community systems are found in the hot and dry zones, whereas the industrial installations are generally located in the humid regions. The records reveal examples of well operated facilities which function effectively through cold and freezing seasons, demonstrating the fact that no hard and fast guidelines on weather impacts can be established under all conditions. This indicates that all climatic factors need not be controlling in the utilization of land application systems.

The bibliographic abstract reference data

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on land application bears out the basic principle that utilization of this process is most common in the Southwest and the mild, drier sections of the Pacific coast, and in such water-short countries as Israel. An article on *Direct Utilization of Waste Waters,* Robert C. Merz,[18] reported that "Land and climate are the primary factors affecting agricultural utilization of wastewaters." An anonymous article, in 1959,[19] reported that "Especially in water-short areas, it is seen that sewage effluent can be put to good use for crops, landscape, decorative lakes and groundwater recharge." Another reference to climatic impacts can be found in an article on *Effect of Geographical Factors on the Widespread Agricultural Use of Sewage in Poland.*[20]

Indications that ingenuities may overcome adverse climatic effects on land application is found in an article on *Experiences of Cannery and Poultry Waste Treatment Operations,* Louis C. Gilde, 1967,[21] "Freezing during the winter has not materially affected operations and the melting of the layers of ice is accompanied by large growths of soil microorganisms which treat the wastes."

An article on *Sewage Effluent Disposal through Crop Irrigation,* C. D. Henry, 1954,[22] refers to plus-and-minus weather impacts: "The use of sewage effluent for irrigation is well known in the arid parts of the U.S. It is practical in the other parts of the country, including the northern parts, where the wastewater can be stored in lagoons during the winter." Further reference to weather effects is found in the abstract of an article on *Some Aspects of Irrigating Grassland in Humid Regions and the Use of Sewage,* G. Julien, 1955:[23] "Higher grass production can be obtained by irrigating during periods of drought when insolation is greater than during rainfalls associated with poor light conditions."

The use of irrigation "through winters with icing" is described in an article on land application by the Heinz Company in New Jersey and Pennsylvania, H. G. Luley, 1963.[24]

These references to literature abstract commentaries on the effect of climate on specific land application installations, demonstrate the need for the local evaluation of each area's weather impacts when land application projects are considered, and that climate alone will not automatically exclude consideration of the method.

Types of Wastes

In general, the preponderance of survey and literature records shows that land application may be used for most types of organic wastes. This includes wastes effluents from municipal treatment plants, with or without industrial wastes, and industry wastes such as those from fruit and vegetable canning, milk processing, pulp and paper wastes, and some chemical wastes. Concentrated organic wastes from industry will require larger unit areas, or lower application rates than those areas and rates utilized for conventionally treated effluents. Toxic wastes and abnormal concentrations of heavy metals should not be permitted in land application systems.

Bibliographic abstract references confirm this generalized statement. *Agricultural Uses of Reclaimed Waste Effluent,* L. V. Wilcox, 1948,[25] refers to "three chemical groupings to be concerned with are trace elements, cations and anions and total salts. Boron is the most important trace element to be concerned with as many plants are injured by concentrations of around 1 ppm. For cations and anions, a good rule to remember is that hard water makes soft land, thus soft water is not desired for irrigation. Generally, sewage effluents are quite suitable for irrigation purposes; toxic materials can usually be diluted to safe limits."

The effect of detergent-based ABS on crops, both adverse and non-adverse, is referred to frequently. The records are replete with references to the successful use of both sewage wastewaters and industrial processing wastewaters for land applicaton purposes.

The build up of chlorides in the soil is the basis of warnings in various articles,[26] and others. In discussing naturally occurring solutes in the *Quality of Irrigation Water,* Wadleigh, Wilcox and Gallatin, 1956,[27] state that "The quality of irrigation water is determined by the kinds of dissolved salts, the relative proportions of certain ions, and the total concentration."

Another reference to the effect of soluble salts in wastewaters is contained in *Water for Irrigation Use*, anonymous, 1951:[28] "Specific ions may accumulate sufficiently to become toxic to certain plants. Boron is highly toxic at concentrations greater than three ppm. The sodium ion tends to cause soil clogging, whereas calcium and magnesium ions tend to make a soil permeable. Thus, there is need for obtaining complete information on the quality of the water (type of wastewaters – community and industrial) to be used for irrigation."

Land Availability and Its Location

The feasibility of land application will depend on the availability of adequate acreage, composed of the proper type of soil, underlain with groundwater at proper level, located conveniently, assigned to proper zoning-use regulations, and viewed with acceptance by residents of the area.

Each site may vary substantially from the acreage needs of other installations because of such factors as soil characteristics, the nature of the applied effluents and indigenous climatic conditions. This makes it difficult to establish hard-and-fast guidelines for designers of land application systems.

The survey data on existing sites indicate that the regions utilized for effluent applicaton are predominantly zoned for farming or industrial uses. This makes the land available, rather than having such areas locked up for urban development purposes, and puts the cost of acreage within the economic range suitable for a process of effluent management that requires more land area than needed for discharge of wastewaters into surface sources. Even when lands used by existing facilities are not formally zoned, they are usually used for farming and related purposes. If such projects were established in close proximity to residential or commercial-business districts, they would run the hazard of failing to receive public acceptance.

Location of sites in undeveloped areas offers projects the opportunity to anticipate growth in community population and increase in industry activity and wastewater production, and to acquire additional land to serve such future needs.

The dependence upon the availability of nearby land sites in close proximity to the points of production of wastes and treatment may have limited the size and capacity of the majority of existing systems to communities of less than 100,000 population, with 50,000 the more dominant maximum community size. It may have had equal impact on the limited size of industrial land application systems.

In all probability, the size limitations of the past may not restrict the use of land application for larger urban regions and industrial operations in the future. In fact, the two major projects now attracting attention – Muskegon, Michigan, and the Corps of Engineers Wastewater Management Study of the Chicago, Illinois, metropolitan region – demonstrate that large-size systems could become realities with the transportation of large volumes of wastewaters to distant open areas. Some existing systems also demonstrate the workability of facilities that are larger than the limitations quoted above.

The relationship between irrigated acreage and community size and industrial production ranges was not clearly defined in the case of many of the existing projects surveyed during the course of the current studies and surveys. However, sufficient data on this relationship were deduced to warrant the following rule-of-thumb guidelines for application areas: the utilization of 10 acres of area per 1,000 population or population equivalency.

> NOTE: Individual installations cannot be designed, nor land acquisition limited, to this specific acreage requirement. Site sizes must be varied to meet climatic conditions, soil composition, wastes character and other local factors. The actual acreage needed for irrigation use may be increased by

standby needs, buffer zones and other site stipulations.

The relationship between land acreage needs and rates of application of wastewaters to the land is obvious. Later discussion of the second factor – rate of application – will bring this interrelationship into focus.

A search of the bibliographic abstract references indicated that while most commonly quoted data related to rates of application, some information on acreage used for specific volume applications is available.

Cannery Wastes Disposal by Spray Irrigation, Leonard E. Nelson, 1952,[29] reported the use of 110 acres of land for 24 mgd of cannery wastes in Minnesota. *Effluent Treatment by Spray Irrigation*, anonymous, 1964,[30] described a New Zealand spray irrigation system for industry wastes which applied up to 65,000 gpd on land areas ranging from three to sixty acres, indicating the broad and unspecific land use parameters in use. An article on *Fundamentals of the Control and Treatment of Dairy Wastes*, H. G. Harding and H. A. Trebler, 1955,[31] referred to a land requirement of one acre per 134,000 gallons per day.

Irrigation Disposal of Industrial Wastes, T. Wisniewski, 1961,[32] reported that spray irrigation in Wisconsin required an acre for 10,000 gpd of application, with land requirements reduced to one acre per 17,000 gpd in California. The author is quoted as predicting rates as high as 800,000 gpd per acre as possible.

Land requirements of 25 to 50 acres per 1,000 population loading for wastewater application onto natural sloping terrain have been reported. In sand dunes in Israel, an acre of land was reported to handle 9,000 gallons per day, in an article on *Sewage Effluent into Sand Dunes*, Dr. Eng. Peter Yehuda.[33]

Soil Types and Groundwater Conditions

Application of wastewaters for irrigation onto land areas would be ineffective if the soil medium will not accept the effluent, allow it to percolate into the groundwater, and provide the natural purification effects which contact with the soil produces. Thus, the nature of the overlying soil blanket and the location of the groundwater table under the land are important factors in dictating the applicability of this process of effluent management.

Sand, loam and silt were found in the surveys to be the predominant soil types used for land application. In some areas, clayey conditions were reported to have no adverse effect on the process. Open-type soils, such as sandy loam, sand and silt, provided the best results at higher rates of application without ponding, especially if excessive runoff is undesirable and a threat to pollution of surface water sources.

In the case of land application by spray overland runoff procedures, tight soils of the clay type are inherent in the success of this system. The soil does not absorb the wastewater, which flows overland along slight grades and is purified by contact with ground cover vegetation.

When soil absorption and percolation into the groundwater table are the natural purification phenomena goal, the groundwater must be sufficiently low to provide enough contact between the applied liquids and dry soil to effect the soil absorptive and adsorptive mechanisms which create a type of tertiary treatment stage in the land blanket. Thus, areas with high groundwater tables, unless underdrains are provided, should not be used for land application systems which anticipate inseepage into the soil. The so-called overland flowage type of treatment described above, and which envisions ground cover contact rather than subsoil contact, would be less affected by high groundwater levels.

One of the study surveys indicated the wide use of clay lands for effluent application (one-third of all installations), thus stressing the fact that the most porous soils are not necessarily the most effective, under certain local circumstances.

The variations in practices relating to soil types offer evidence that no single guideline can dictate decisions on the kind of land most adaptable for land application practices. The most dependable means of ascertaining soil capabilities would be to have the indigenous soils evaluated by agronomists and soil mechanics authoritites. Most soils are composites of many types of materials. The nature of the effluent to be applied to land areas will have a great bearing on the absorptive and adsorptive capabilities of the soil mantle.

Since the best evidence of successful soil types can be found in the performance of existing installations, further guideline parameters are available in the literature. References have been made above to the effects of solutes, or dissolved solids, contained in wastewaters on the mechanical and chemical format of soil media.

An article on *An Investigation of Sewage Spreading on Five California Soils,* G. T. Orlob and R. G. Butler, 1955,[34] stated that: "The infiltration rate for each soil was found to follow the same general pattern: (1) an abrupt decrease in rate attributed to suspension of soil particles; (2) an increase in rate due to solution of entrapped gases into the percolating liquid; and (3) a decrease due to accumulation of biological slimes in the soil voids. Infiltration rates in the third stage ranged from 30 feet per day for the most permeable soils to 0.6 feet per day for the fine soils." It made the further point that "field performance of a soil cannot be predicted by comparing its particle size characteristics with those of other soils for which infiltration rates have been established."

The authors of *Septic Tank Effluent Percolation through Sands under Laboratory Conditions,* Joe H. Jones and George S. Taylor, 1965,[35] reported that "Soil clogging under effluent loading occurs three to ten times faster under an anaerobic than under an aerobic environment, and sands of initially high hydraulic conductivity are clogged at a much slower rate than those of initially low conductivity."

Sewage Irrigation in Texas, Earl H. Goodwin, 1935,[36] stated that "Porous sandy soils seem to be most suitable" for such crops as grains, grasses, cotton, alfalfa, nuts and citrus. An abstract of *Spray Disposal of Domestic Wastes,* William J. Chase, 1960,[37] stated the conclusion that "Deep silty soil is preferable. Clay subsoil may lead to bad effects from adsorption of sodium through ion exchange."

The importance of soil "freeboard" between land surfaces and groundwater tables has been repeatedly stressed. The mechanics of soil uptake and stabilization of contaminants such as phosphorous, boron, ABS from detergents and nitrogen forms, depends on adequate depth of groundwater. *Degradation of Wastewater Organics in Soil,* R. E. Thomas and T. W. Bendixon, 1969,[38] stated that "The results of Lysimeter studies show that soil microorganisms can digest much of the organic carbon contained in primary and secondary wastewater effluents. About 80 percent of the organic carbon from septic tank effluent was digested under a variety of conditions."

The abstract of *Effects of Treatment Plant Effluent on Soil Properties,* A. D. Day, et al, 1972,[39] reported that "the effluent irrigated soil has higher concentrations of soluble salts, nitrates, phosphates, calcium and magnesium than the control, due to the uptake capacity of soils above the groundwater table."

The importance of unsaturated soil in the land application system is the subject of many bibliographic abstract references. The *Feasibility of Reuse of Treated Wastewater for Irrigation, Fertilization and Groundwater Recharge in Idaho,* R. E. Williams, et al, 1969,[40] referred to "absence of surficial, jointed rocks through which the wastewater can move without appreciable adsorption of dissolved solids by the porous medium; and a water table depth of at least five feet." An abstract on *Final Report on Field Investigation and Research on Wastewater Reclamation and Utilization in Relation to Underground Water Pollution,* Harold B. Gotaas, 1953,[41] concluded that "A bacteriologically safe water can be produced from settled sewage or final effluent if it passes through at least four feet of soil."

Groundwater Recharge Design for Renovating Wastewater, Herman Bower, 1970[42] reported that "Purification by the soil is accomplished within several feet although it is considered desirable to allow the water to flow for several hundred feet before reuse."

According to an abstract on *Los Angeles Considers Reclaiming Sewage Water to Recharge Underground Basins,* Harold E. Hedger, 1950,[43] "Experimental tests have shown that the percolated effluent is bacteriologically safe within a depth of seven feet." On the other hand, *Microbial Problems in Groundwater,* G. G. Robeck, 1968,[44] refers to the "need of a more specific indicator of fecal organisms, and the need for removal of waste that might be food and nutrient for the organisms before wastewater percolates down more than one to two feet."

Arnold E. Greenberg and Jerome F. Thomas, in an article on *Sewage Effluent Reclamation for Industrial and Agricultural Use,* 1954,[45] reported that "A bacteriologically safe water can be produced from settled or more highly treated sewage if the liquid passes through at least four feet of soil."

Rate of Application

The significance of rates of application of wastewater effluents to land areas has been discussed previously. Application rates have a direct bearing on the acreage required. Conversely, the nature of the soil has an equally great effect on the rate of application which can be successfully handled by the land site.

With a fixed design flow, the application rate will determine the area required for the facility. An empirical rate of two inches per week has become "standard" practice in many installations, but each site should use an application rate which is geared to the type of soil, kind of wastewater, type of application, gradient of the site, seasonal rainfall and other climatic conditions, and frequency of application. The difficulty in fixing the area required for a proposed site without basing estimates on some fixed application rate is evident.

The two-inch-per-week application rate has been accepted widely with too much alacrity, but without positive proof that this rate is suitable for the specific site and the soil capabilities of the site. Any guideline that offers a firm application rate without further substantiation of its validity is misleading. One of the needs of land application practices is to ascertain the maximum application rate that will test the soil assimilation capabilities to the "failure point" – or, in land application practice, to the "point of refusal" to accept wastewater discharges. With optimum types of soil, it is probable that loading rates can far exceed present applications and that economies in land acreage utilization can be sharply improved without any impairment of land, crop yields or groundwater quality. This dictates a specific guideline of design: each site should be evaluated to determine maximum optimum loading rates before actual land purchase is consummated and design of facilities is undertaken.

The existing literature on current and past experiences with land application systems offers proof that rates of application need not be based on any conjectural standard of loading. Bernard Skulte, in an article, *Agricultural Values of Sewage,* 1953,[46] reported rates of 4,600 gpd per acre. Gilbert Dunstan and Jesse Lunsford, in an article on *Cannery Waste Disposal by Irrigation,* 1971,[47] reported that a Daytona, Wash., cannery applied at least seven inches per week to alfalfa crops. With ridge and furrow application methods, rates as high as 2.25 inches per day were cited at the 1952 Purdue Conference on Industrial Wastes.

G. W. Lawton, et al, in an abstract of an Engineering Experimental Station research project in 1960, reported[48] that "realistic average application rates of 0.23 inches per hour were realized with cover crops of blue grass, quack and brome." An abstract of *Experimental Spray Irrigation of Paperboard Mill Wastes,* D. E. Bloodgood and Harold

C.Koch,[49] 1959, reported that the "Average rate of application was 0.28 inches per day, of which 0.08 inch was rainfall."

An article abstract on *Irrigation Disposal of Wastes,* Ray Westenhouse, 1963,[50] reported that "Application rates of 0.5 inch per day produced slight surface flooding." C. D. Henry, et al, described *Sewage Effluent Disposal through Crop Irrigation,* 1954,[51] and reported that "This test, done in Madison, Wisconsin, applied more than 50 inches of water per season, producing substantial increases in crop yields. Nitrogen, potassium and phosphorous were almost totally removed from the effluent as were coliforms." "A percolation rate of 0.5 acre foot per acre per day when spreading final effluent on Hanford fine sandy loam" was reported in an abstract of *Sewage Effluent Reclamation for Industrial and Agricultural Use,* Arnold E. Greenberg and Jerome F. Thomas, 1954.[52] At another site, "Disposal of effluent has occurred since 1911, where it is applied to meadows at a rate of 6.6 feet from March to December. In the remaining interval, it is applied to a plot of arable land, even when the land is frozen." *Sewage Farming at Ostrow Wielkopolski,* 1950.[53]

The Howard Paper Mills of Urbana, Ohio, reported the application of process wastes "at a rate of four inches per day every six days," in an article abstract on *Spray Irrigation–a Positive Approach to a Perplexing Problem,* W. A. Flower, 1965.[54] Food processing wastes were applied by a "sprinkling system at 0.44 inch per hour," as described in an abstract on *Spray Irrigation at Morgan Packing Company, Austin, Ind.*, Perry E. Miller, 1953.[55] Sulfite pulp mill wastes were applied at a "rate of 3.6 inches per week to highly permeable Norfolk sand," as reported in an article abstract on *Spray Irrigation of Certain Sulfite Pulp Mill Wastes,* Stuart C. Crawford, 1958.[56]

"The use of sewage effluent at Pennsylvania State University on forested areas showed that the trees benefited as shown by increased growth, and about 90 percent of the water applied from April-November at a two inch per week rate was recharged to the groundwater," according to William Sopper in an article on *Wastewater Renovation for Reuse: Key to Optimum Use of Water Resources,* 1968.[57] The same author reported the application of sewage effluent at Centre County, Pa., "at a rate of 0.25 inch per hour, at one to two inches per week except in one plot which received four inches per week."

Methods of Application

The choice between application of wastewaters to land areas by spray irrigation or methods utilizing surface spreading can be likened to the engineering choice between concrete or bituminous paving for streets and roads. The decision should be made on the basis of land and crop needs, on whether deciduous forested areas will be irrigated, on the soil character and natural gradient of the site, and on other local conditions such as aerosol dispersion and odor production. The comparative cost factors must be considered, including the question of gravity or pressure distribution.

Spray irrigation will involve the construction of distribution pipe lines, either stationary or moveable, the installation of pumping equipment and time-cycle devices. The comparative labor costs of spray irrigation, ridge-and-furrow distribution, overland flooding or other means of land application will become a factor in decision-making and in design procedures. These decisions will have a direct bearing on operation and maintenance costs and control of environmental impacts. The type of soil cover, including the anticipated cropping practices, will require evaluation. The views and opinions of neighboring residents may influence the application methods chosen for the site.

No general rules can be deduced from the surveys conducted in connection with the current investigation. However, spray irrigation predominated in the sites surveyed. Ridge-and-furrow distribution and overland flow or flooding methods followed in general applicability. A general trend appeared to emerge on the relationship between application methods and size of sites. More spray facilities are in use in smaller acreages, less than 50 acres, with surface and spray methods approaching equal utilization as the sites increase from approximately 200 acres to the 1,000 acre size. For sites over 1,000 acres, surface distribution predominated.

The impact of climate conditions was noticeable in the on-site investigations, with surface application predominating in the drier and hotter regions and spray irrigation more widely used in the more humid areas. In similar manner, the continuity of application influenced the choice of application method. For example, the irrigation of forest stands of deciduous trees during winter months, even in severe climates, was found feasible with spray irrigation. Nondeciduous trees, because of ice buildup may be damaged by spray irrigation during freezing conditions, but some success with evergreens has been reported. Coniferous stands offer the advantage of year-round nutrient uptake. In addition, the thick layer of forest litter hinders freezing of the soil, retaining the soil's percolation capacity during very cold weather.

The large land application projects which have recently been proposed all depend upon the use of large-scale spray irrigation techniques.

The literature indicates that all methods of application have been in use in the U.S. and other countries. The purpose of land application, whether for crop enhancement, groundwater augmentation, or specifically for the purpose of disposing of effluents without recourse to discharge into water sources, tended to influence the choice of methods utilized. For example, wastewater application to golf courses and to highway median strips could best be accomplished by spray distribution. In the case of golf courses, early morning applications were suggested in researched literature but it is known that distributors are often in use during playing hours.

Holding Facilities and Seasonal Application

A potential gap may exist in some installations between the rate and continuity of wastewater production and the ability of the land to accept the application of effluents. In the case of community systems, wastewaters are produced on the basis of 24-hour flow, every day of the year, but normal variations in momentary and hour-to-hour flows are experienced. In the case of industries, wastewater may be produced seasonally, in the food canning industry for example, and flows may be limited to the days and hours of plant operation.

In addition, normal, or abnormal periods of precipitation may affect the acceptance rate of wastewater onto the land; periods of drought may require more auxiliary irrigation than available with the fixed continuity of wastewater production from community and industry sources. Winter weather may require the cessation of application or a marked reduction in rates.

These variable factors must guide decisions on whether holding facilities should be provided, at either the wastewater treatment plant or on the application site. The findings of the surveys offer some frames of reference for determining the need for storage or holding of effluents to iron out variations in flow and land application rates, or to retain volumes of irrigation waters for use during variations in need and land acceptance. It was found that over two-thirds of the community systems and under one-half of the industry installations function more or less on a year-round basis. Regional differences were found, as might be expected because of climatic impacts on irrigation practices. Operation periods range from two to twelve months, reflecting the general purpose of land application and whether only part of the produced flows of wastewater is diverted to land areas.

The daily continuity of land application varies widely. Some systems apply wastewaters only one day a week; others utilize this method of discharge every day of the week. In general, the community and industry systems which function less than seven days a week are in the smaller size groupings, with flows less than one mgd. The predominance of five, six and seven-day operations indicates that continuity of flows, or use of stored waters, induced relatively continuous service.

To meet these flow and application conditions, most land application systems utilize some type of holding ponds or chambers. Approximately 90 percent of the resspondents to the mail survey reported the use of holding facilities. Minimum storage periods showed no specific pattern relating to size of installations. Minimum storage ranged from one day to 10 days. Holding pond capacities, in turn, varied in size, with some of the lagoon type containing more than 50 million gallons.

It is understandable that seasonal holding in systems which produce wastewaters year-round but where climatic conditions prevent 12-month land application, must provide large holding capabilities, usually located on the land site and taking the form of natural basins or lagoons that are then drawn upon during the growing season. Otherwise, the discharge of wastewater effluents to receiving waters during part of the year or part of any day or week would make ineffective the intent of the alternative management system made possible by land application.

References to holding pond facilities in existing installations are meager in the literature. According to a report on *Disposal of Liquid Wastes by the Irrigation Method at Vegetable Canning Plants in Minnesota,* delivered at the 1952 Industrial Wastes Conference at Purdue,[58] six plants using spray and ridge-and-furrow distribution operated satisfactorily. "No odors were encountered with the use of fresh wastes, although lagooned wastes did produce odor problems." This indicates that holding wastes under anaerobic conditions may result in septic conditions.

On the other hand, lagooning was described as "a means of reducing pollution before spraying" in an abstracted article on *Effluent Treatment by Spray Irrigation,* 1964.[59] Lagooned wastes were used in a spray irrigation simulated study described by the U.S. Department of the Interior, 1970, on the *Engineering Feasibility Demonstration Study for Muskegon County, Michigan, Wastewater Treatment Irrigation System.* [60] "Lagooning and irrigation are desirable," in the opinion of Edward F. Eldridge, in an abstract of *Industrial Wastes – Canning Industry,* 1947.[61]

An abstract of an article on *Irrigation with Sewage,* 1938,[62] reported that "a storage lake and land irrigation solved the sewage disposal problem at Kingsville, Texas. The storage lake makes the system quite flexible." R. R. Parker, in an abstract of *Spray Irrigation for Industrial Waste Disposal,* 1965,[63] reported that a Canadian tannery uses a spray irrigation system "that disposed of 150 million gallons in a six-month period from May to November for the past 12 years. Winter wastes are lagooned."

Pre-Treatment of Wastewaters

In past installations of land application systems, no standard procedure was applied on degree of treatment of wastewaters prior to distribution on community and industrial irrigation areas. Although 45 percent of the community systems handled secondary effluents on their land areas, the remaining installations applied either primary effluents or wastewaters which had been treated in some form of oxidation ponds or other non-secondary facilities. Approximately one-half of the community installations chlorinated their wastewaters prior to land application. Industrial systems reported the use of only preliminary treatment, generally consisting of screening to remove larger suspended solids.

The survey indicates that the level of pre-treatment of wastewaters has been dictated by the requirements of state agencies. Secondary treatment of municipal wastewaters or long detention in lagoons appears to be a reasonable standard for land application. Where wastewaters are to be spray-irrigated or applied on land used for recreational purposes, chlorination prior to application appears warranted. Industrial wastes need only that degree of pre-treatment that will allow spreading to be accomplished without imposing undue loadings and physical problems on land application sites.

References to degrees of pre-treatment of land-applied wastewater effluents in the literature abstracts offer little guidance other than to confirm that modern practice precludes the delivery of inadequately treated flows to land areas.

An article on *Texas Approves Irrigation of Animal Crops with Sewage Plant Effluents,* G. R. Herzik, Jr.,[64] places the pre-treatment problem into focus. The abstract outlines the point of view of the State Department of Health, as follows: "Do not favor use of raw sewage for irrigation regardless of type of crop. Sewage effluent receiving at least primary treatment may be used for irrigation, but not for crops for human consumption. Encourages use of primary treated, and preferably completely treated, sewage in feed and pasture crops used for animal consumption or as an adjunct to soil conservation practices."

The literature contains repeated references to primary pre-treatment of wastes, less frequent indications of secondary treatment, and even occasional references to tertiary treatment levels for land-applied effluents from sewage treatment plants. Industrial wastes have received minimal treatment, often limited to only screening. Chlorination to disinfect wastewaters of human origin, and to depress septicity of industrial processing wastes, has been common practice at sites covered by this study's on-site and mail surveys.

Capital and Operation Costs

A minimal amount of data on costs can be deduced from surveys conducted in connection with this project, and some facts can be gleaned from the literature.

In lieu of dependable cost data on initial investments and on ultimate operation and maintenance practices, rationalization of the various factors of any cost structure for a land application system can be offered. Land application of effluents is relatively simple and no expensive processes or products are involved. Costs should be considered as ancilary to wastes treatment facilities; they should start with, and should include the cost of, transporting treated effluents to land areas either by gravity channel, gravity pipe line, or pressure piping. On-site, the costs involved should include the cost of land, distribution systems with any piping, spray units and pumping items involved. Where underground water intercepting or overland flow collection conduits are utilized, the cost of such facilities must be included. Holding or storage units must be priced. The cost of supplemental chlorination or chemical additions, such as sodium nitrate for oxidative purposes, should be computed as part of land application systems.

For operation and maintenance, the items of cost must include labor, power, replacement of piping and distributors, safety patrols, monitoring and laboratory control services and other obvious costs. Each project will involve special costs peculiar to the system.

Survey data indicated that land costs varied from a minimum of a few hundred dollars per acre to $1,000 or higher; the normal costs were under $1,000, with the majority of sites in land regions where costs are approximately $500 per acre. The relationship between zoning and land-use and site costs is obvious.

Total capital cost data for land application systems were meager but some information could be deduced from the study surveys. Many cost totals were small – under $10,000 for handling flows up to one mgd. A few installations in the same size range cost as high as $500,000, indicating that there was no direct correlation between system capacities and capital costs. The question of whether pre-treatment facilities were included in the cost base was not clearly defined.

Some references to costs and returnable incomes from crop harvesting or use of wastewaters by purchasers, such as farmers, were found in the bibliographic abstracts covered by the project. Furthermore, some efforts were made by authors of articles to place a price ticket on the value of land application systems, in terms of removal of contaminants which would have required costly wastewater handling processes in standard treatment works.

For example, a study of wastes handling at the Campbell Soup Company at Paris, Texas,[65] placed a cost of five cents per 1,000 gallons for removal of 99 percent of the BOD, and nitrogen and phosphorous removals of 90 percent. *A Technical and Economic Feasibility Study of the Use of Municipal Sewage Effluent for Irrigation,* Robert P. Cantrell, et al,[66] included design data for a Louisiana farm of 114 acres and quoting a total fixed cost and operating cost of $39 per acre.

An abstract on *Cannery Waste Disposal by Irrigation,* Gilbert Dunstan and Jesse Lunsford,[67] stated that "field irrigation was successfully used at one-fifth the cost of a high-rate trickling filter." Another article citing the experiences of the Campbell Soup Co., Paris, Texas, 1970,[68] reported "an operating cost of about five cents per 1,000 gallons." A 1951 abstract on *Disposal of Citrus By-Products Waste at Ontario, California,* Harvey Ludwig,[69] reported that the "Cost of operation is about 12 cents per ton of fruit processed." A 1967 account of *Spray Irrigation from the Manufacture of Hardboard,* Ward Parsons,[70] estimated the land application facilities had been provided at "total costs of about $50 per million gallons, not counting land or depreciation."

Industry cost data were more often available than those for community wastewaters. The tendency for industry, as might be expected, was to relate costs to units of production. For example, in 1953 *Spray Irrigation of Food Processing Wastes,* Joseph M. Dennis, [71] stated that "Costs have been reported as $0.006 per case of goods sold."

Protective Measures

Fencing and patrolling of application sites have been matters of self-determination in existing installations because few states have invoked rules and regulations on operation and control procedures. Few operators have deemed such protection and isolation essential to the safety of neighboring areas and their residents.

Protective measures are more than devices to keep people *out;* they must be designed to keep land application ingredients *in.* The provision of buffer zones to serve as more or less impenetrable barriers of a two-way nature are referred to in a few of the limited number of state regulations relating to land application systems. Various geographical dimensions of buffer barriers are stipulated or, if not designated, are used by developers of land sites. Their size and locations are dictated, in part, by the means of wastewater application and windward and lee-side conditions. If utilized, this acreage of land must be purchased for projects and adequately maintained during the life of the project.

Reference to barriers is contained in an abstract on *Investigation on the Spread of Bacteria Caused by Irrigation with Wastewater,* H. Reploh and M. Handloser, 1957.[72] It stated that: "at high wind velocity, very small droplets containing bacteria are spread considerably beyond the proper zone of action. When the use of sprinkler equipment is projected, this must be taken into consideration and strips of land of sufficient size provided for protection from the spread by wind. Probably, the zone spread can be safely lessened by planting hedges for protection from the wind."

Monitoring and Health Hazards

Practically all standard wastewater treatment and industrial wastes treatment works in the U.S. are required to sample and analyze their incoming wastes and the wastewater effluents which they discharge to surface water sources. The requirements of the 1972 amendments to the Federal Water Pollution Control Act are so firm on the subject of monitoring that quality surveillance and control and a rigid program of reporting effluent quality will be enforced by Federal and state regulatory agencies.

The present concept of water resources and water quality control includes groundwater sources as well as all surface waters. It is obvious, therefore, that all land application systems must be planned, designed and operated under adequate monitoring conditions. The degree and extent of monitoring should be predicated upon the use of the land application facility. If all flows are essentially being used as supplemental irrigation and groundwaters will become the recipient of infiltered waters, an adequate monitoring program may be required. As the degree of safety is reduced and the system stressed, more stringent controls are needed.

Small installations, which are common in current practice, will find it expensive to provide monitoring facilities, such as test wells or Lysimeters, and to undertake ongoing laboratory test programs for wastewaters, soil, crop yields, groundwater and nearby surface water sources. Only a relatively small percentage of existing installations are now under monitoring control, judging from the surveys.

Off-site effects of land application operations have not been monitored to any appreciable degree. Few, if any, installations have traced the effect of land-applied wastewaters on nearby surface water sources, either in the form of contaminants which run off the soil or groundwaters which out-seep into drainage basins. Further, little has been done to evaluate the beneficial effect of land application on surface waters which would have been the recipients of effluent discharges if conventional treatment and disposal methods had been used instead of land application techniques.

The literature indicates the need for monitoring of groundwaters, crops, soil and animal life. References are made to potential health hazards if adequate care is not taken in the handling of wastewaters and the control of crop usage. Effluent disinfection is referred to in many cases as the essential component of any land application program. The "other side of the coin" is illustrated in such abstracted comments as "Hygienic risks should not be overestimated," in an article by W. Fries on *Agricultural Utilization of Sewage as Artificial Rain.*[73] This author also referred to the need to evaluate "the toxicity of wastewater to germinating plant seeds."

The presence of coliform organisms, salmonella, cyst eggs and virus are acknowledged by the authors of a number of reference articles – (74); (75); (76); (77); (78); (79); (80); (81); (82); (83); (84); (85); and others.

The actual referenced statements need not be included here; the point is made that the presence of potentially hazardous organisms in wastewaters precludes the use of raw or under-treated sewage on land areas; but this does not negate the fact that adequate treatment, disinfection and control procedures on-site can minimize or completely overcome such hazards. The purification capabilities of soils, with their uptake of contaminants, must be considered in the true definition of land application.

A search of the land application experiences documented in the study's bibliography has disclosed assurance of freedom from environmental and personal hazards that balance and contravene the warnings of potential dangers if adequate regulatory procedures are not invoked. Without specific references to articles and authors, the following quotes from abstracts on practices, performances and personal opinions are presented:

"Strains of *Salmonella* and *Shigella* do not survive on vegetable surfaces for more than a week." "Vegetables to be eaten raw can be grown without health hazard in soils subjected to sewage irrigation."[86]

"It is concluded that virus movement through soils under saturated conditions should present no great health hazard with respect to underground water supplies."[87] "Virulent bacteria were not present in sufficient concentrations in the incoming sewage, effluent or sludge to cause disease in susceptible animals."[88]

"Coliform organism reductions are well documented . . . but viruses still remain a problem, although chlorination is quite useful."[89] "Disease transmission has been non-existent."[90] "The amount of virus removed by two feet of sand varies with the flow rate, but in almost every case the virus was removed amazingly well."[91]

"The recreational lake samples have been consistently negative for virus."[92] "The soil is capable of removing viruses after a distance of less than 1,500 feet."[93]

"Diseases among farm animals, workers and residents have not been a problem."[94] "Epidemics caused by contaminated food have been due to mishandling in processing."[95]

The Department of the Army, Medical Department, through the Surgeon General, developed extensive criteria for land application facilities on the basis of reports prepared by the Corps of Engineers and Pennsylvania State University.

The criteria can be characterized as very conservative and they appear to be at variance with the experimental work which was used as their basis. However, inasmuch as they attempt to set forth a rationale for the criteria established, a copy of the criteria and rationale are included as Appendix F of Section XI of this report.

Land application of wastewater effluents is a means of disposing of such liquids into the soil body and of utilizing the water content and the nutrition components for enhancement of soil fertility and crops.

Ground Cover

The study provides some degree of guidance on the types and value of ground cover growths in aiding the soil absorptive and adsorptive character of the soil mantle and on the types of vegetative crops and forestry growths which are benefited by artificial irrigation.

The on-site surveys disclosed that grass land cover and crops were most predominant in community systems and that grass, without crop growth, was favored in the case of industrial land application installations. The use of community-produced wastewaters for agricultural crops was strkingly pronounced in the Southwest and the southern sector of the Pacific coastal states. The consensus was that some form of ground cover, without disturbance of the indigenous mantle, served as an aid to soil infiltration and increased the acceptance of irrigation wastewaters into the land.

The conclusion was drawn by most users of effluent on crops that marked increases in yield resulted and that the quality of product was not sacrificed. Similarly, silviculture authorities were of the opinion that tree growth was increased, and even doubled, as a result of irrigation, which could be carried out during winter months without impairing the life and growth of deciduous and even nondeciduous tree life. Insufficient information was obtained upon which to base any definable estimate of the dollar value of harvested forage growths, crop produce or tree wood, but no doubt can exist that monetary values can be assigned to land application practices. Each installation must be judged on the basis of types of soil, amenability of climatic conditions, the nature of the proposed plantings and other factors, when the economics of land return are considered.

The literature examined disclosed considerable information on the types of plantings, even if explicit data on increased yields could not be deduced from the experiences and opinions of the authors. The following excerpts from literature abstracts are presented without providing the titles and authors.

"Irrigation with sewage water increased the yields of hay by 300 to 400 percent, cereals by 20 to 50 percent, and root crops by 100 percent; and it increased the protein content in hay from 6 to 17 percent."[96] "The author advocates broad irrigation with emphasis on the utilization of sewage for the growing of crops, rather than as a method of sewage disposal."[97] "After the cessation of the spraying after six weeks of operation, superior crop yields were realized."[98] "Barley, oats and wheat showed superior growth when irrigated with sewage effluent."[99]

"The application of sewage effluent to barley resulted in an increase grain yield, percentage of nitrogen and malt diastatic power, but kernel weight, kernel size and malt extract percentage were decreased."[100] "City sewage effluent can be utilized efficiently to produce hay from small grains in the irrigated areas of the Southwest and possibly elsewhere in the United States."[101] "Grasses were used for cover vegetation. Alta fescue was found to have high moisture resistance and reasonably high salt tolerance."[102]

"The use of reclaimed sewage effluent for agricultural and horticultural purposes represents not only sound water economy but also good fertilizer economy. It is estimated that the fertilizer value in sewage effluent from the Aisleby Works at Bulawayo is about seven cents per 1,000 gallons."[103] "Cases were cited where very poor sandy land has been converted to good, productive farmland by sewage irrigation."[104] "Yields of barley were 212 percent times its control and oats yields were 349 percent times its control."[105]

"The study area (at Penn State) consisted of mixed hardwood, red pine."[106]

"Cotton is a most satisfactory crop. In 1934, 24 acres of irrigated land produced 23 bales of cotton. Dry land produced less than one-third bale per acre of poorer quality cotton."[107] "Crops of oats, barley and ensilage are rotated on the land. The crops yield a net profit of $3,000 to $5,000 per year to the city (Tucson)."[108] In Texas, "Spray, border and furrow methods are used to irrigate grains, grasses, cotton, alfalfa, nuts and citrus."[109]

"A herd of over 600 fine Hereford cattle are maintained on the farm. For the fiscal year ending June 30, 1949, the city (Fresno, Calif.) realized an operating profit of $9,346."[110]

"Eastern European countries have obtained yields 5 to 6 times the normal by using sewage for irrigation."[111] "Application of sewage water for three years to grassland raised the hay yield by 132.9 percent and the yield of crude protein by nearly 300 percent."[112] Irrigation with sewage is beneficial to plants despite the presence of ABS in any amounts likely to occur in sewage at the present time."[113] "After sewage solids are removed, 80 percent of the potassium, 75 percent of the nitrogen and 52 percent of the phosphoric acid remains, making the effluent a valuable fertilizer."[114]

Need for Further Information on Land Application Practices

If there is to be a substantial increase in the use of land application methods, especially for community wastewater effluents, there will be need for basic data covering many of the problems which will influence distribution methods, soil choice, testing and control, and operation and maintenance procedures.

The following facets of land application could be studied to provide effective answers to problems not yet adequately resolved:

1. Investigate the design of small sized, simplified irrigation systems for rural communities or small community developments which currently use septic tanks in unsewered areas, including the feasibility of injecting sludge into the wastewater effluent prior to application onto land areas.
2. Investigate the optimum design of small-scale settling facilities for such small rural flows, followed by adequate secondary treatment and chlorination to make effluents amenable to safe land application at nearby sites.
3. Develop cost analyses for various land application techniques so they can be contrasted with each other and cost-factored against investments in conventional high-degree wastes treatment and discharge of effluents into watercourses, taking into account any crop-yield profits which may accrue from land application facilities.
4. Investigate disinfection procedures, with chlorine or other chemical additives or nuclear wastes materials, for small and large land application installations, to determine the probable life of pathogenic bacteria and various strains of viruses under conditions that occur under soil, groundwater, and crop growth

conditions.

5. Additional fields of investigation may include: evaluations of the benefits and need for buffer zones surrounding land application areas; examination of the ability of aerosol droplets and mists to carry contamination; establishment of criteria for holding basin design; and study of the fixation of nitrogen as a soil oxidizing factor.

If land application of community and industrial wastewaters is to become a viable solution for effluent management and offer workable, applicable, economical and useful water pollution control alternatives to the ultra-treatment of wastes and their discharge into receiving waters, all facets of the impact and effect of such installations must be examined. The process offers sufficient potential benefits to warrant the investment of time, effort and funds in such investigative goals. The research suggestions listed above are intended merely for the purpose of catalyzing interest in a deeper insight into land application processes, practices, policies and performances than has as yet been sought or provided.

SECTION VII

LAND APPLICATION OF EFFLUENTS IN PERSPECTIVE: AN INTERPRETATION

The practicability of the application of sewage and wastes effluents onto land areas rather than directly into water sources is dependent, as are other means of treatment, upon complex and interacting circumstances and conditions.

Changes in Effluent Disposal Practices: Trends and Prospects

This "alternative" method of disposing of wastewaters which could affect the quality and usefulness of surface waters, or require advance degrees of treatment to prevent such adverse effects on the water environment, has been under intensive and extensive study and evaluation, particularly in recent years.

The basis for acceptance of land disposal, or "sewage farming" as described at the turn of the century by M. N. Baker in his historic pamphlet, *Sewerage and Sewage Disposal,* a page of which is shown in Exhibit IX, is no longer adequate to meet new approaches to, and concepts of, land application systems. The propriety of this process has been investigated to demonstrate its applicability to the clean-waters criteria of the 1970's and the economic, ecologic and effectiveness factors involved.

The study by the American Public Works Association is one of the several investments of scientific time and funds to put the land application process into proper perspective with so-called conventional methods of discharging effluents of varying degrees of purity into watercourses.

It is apparent that any decisions to utilize effluent land application methods, in lieu of treatment and discharge of high grade effluents into surface waters, must be based on facts which will establish the process as the best alternative "practicable waste treatment technology" and one which will provide effective disposal "over the life of the works," in consonance with the intent of the Federal Water Pollution Control Act Amendments of 1972. Decisions thus arrived at must involve consideration of the factors covered by the current study.

There is nothing new about the basic concept of spreading sewage or other liquid wastes, in treated or untreated form, on the land as a means of disposal. What is new is the objective of making this method of disposal a scientifically evaluated, technically designed, and properly operated and maintained treatment procedure which can meet the criterion of a "best practicable technology." Also of relatively new significance is the more specific definition of land application as referring to the application of effluents onto land areas after degrees of treatment approaching those normally required for effluents discharged to receiving waters. The application of sludges or wastewater residues to land areas is a supplemental ramification of effluent land application.

Land application of sewage predates any known artificial means of treating liquid wastes prior to discharge into receiving waters. Even though early practice involved the disposal of untreated wastes onto farm properties, it had the merit of providing the "purification" which absorption, adsorption and mechanical retention on soil particles and in their interstices could accomplish. It was better than discharge by dilution into watercourses.

Actual application of sewage to the land can be dated back to periods prior to the development of sewer systems. Municipal wastes were discharged onto nearby farms at Berlin, Germany, as far back as the 16th century. In Scotland, fields in the vicinity of Edinburgh were used as the recipients of sewage in the 1840's; Berlin purchased tracts of land for sewage irrigation purposes in 1869 and various English communities utilized farm lands for sewage farming during the last three decades of the nineteenth century.

With the turn of the century, United States cities in Wyoming, Utah, Montana, and California applied sewage to farmlands for

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crop improvement or groundwater supplementation. In Texas, San Antonio initiated irrigation with sewage or sewage effluent on over 3,000 acres of land in 1900. The use of some form of treated effluents for land disposal purposes, rather than raw sewage application, dates from the 1930's. A land irrigation system using untreated sanitary wastes of the City of Mexico City D.P. was begun in 1902 and expanded to the use of secondary effluent for watering farmlands, sport areas, and creating artificial lakes in recent years. Among the other cities surveyed for this report, 10 were established before 1920 and 10 more by 1940, with 26 municipal systems begun since 1960.

An "Alternative" Represents a Choice of Disposal Processes

If land application of effluents is a valid alternative method of wastes treatment, it is obvious that it is an alternative to other means of disposal. Among the alternatives of disposal management techniques are:

1. Treatment to adequate degree and achievement of effluent qualities, accompanied by the discharge of the wastewater into surface water sources–the so-called conventional method of effluent disposal management
2. Treatment of sewage or industrial wastes, or combined sewage-industrial wastes, by advanced methods, to a high degree of purification, followed by direct reuse for limited purposes; as a processing fluid; as a general-use fluid; as a recreational commodity; or even eventually as a source of potable water for domestic purposes. Another use would be for groundwater replenishment which can then be utilized by indirect or secondary recycling for use as groundwater potable or processing supplies; or as augmentation of groundwater for the purpose of providing a hydraulic barrier to the intrusion of saline waters into underground aquifers or the invasion of other unwanted waters, such as brackish field waters into quality groundwater sources.
3. Application of adequately treated effluents of municipal sanitary sewage or commercial-industrial process wastewaters onto land areas. This is the *alternative* method of effluent disposal management which is the subject of this report.

The purpose of this section is to place land application, as an acceptable alternative technique of effluent disposal, into perspective with the other two categorical methods of disposal. Stated in another way, land application decision must not be made without full evaluation of its economical and ecological merits, and its effectiveness as compared to other means of disposal. Such an evaluation is presupposed by the requirements of the 1972 Amendments to the Federal Water Pollution Control Act. It involves a weighing of the advantages and limitations of each method of disposal in relation to the other alternatives, and the examination of the comparative merits of each.

This section focuses attention on the general comparison factors which must be balanced in determining the applicability of land application management procedures. This can best be done by briefly reviewing the principles involved in the three alternative means of effluent disposal, as outlined above.

The basic function of discussing these management techniques is to give depth and dimension to the single-target examination of land application practices, policies and performances which the contract studies covered and which this report has described. To meet this purpose, the following commentaries on watercourse discharge, groundwater percolation and land application methods are presented.

Discharge of Effluents into Surface Water Sources

Any wastewater disposal management technique must have its validity as an alternative method weighed against the conventional procedure of treatment and discharge into surface water sources. This is recognized practice; it is the means of disposal which has been the focus of water pollution control. The question has not been raised as to whether treatment should be provided for wastes flows; the query has been "how much treatment" to provide effluents which can be assimilated in receiving waters without impairment of their quality or diminishing their usefulness.

The return to water sources of the waters taken from them has been viewed as a natural procedure of water to water. Rivers, lakes and coastal waters have been traditional recipients of wastewaters – used water – since public sewer systems and industrial drain facilities were first installed. They have been convenient, in fact too convenient, and the natural hydraulics of stream locations made them easy points of disposal by gravity at the outset, and then readily used by pumping where this expedient was required.

Disposal by dilution has been so cheap that no other means of disposal could compete with it in terms of costs. Today, with new concern for advanced degrees of treatment to provide higher levels of effluent quality, the discharge of untreated wastes by some local agencies into surface waters is still practiced. This anomalous condition can no longer be condoned and all available alternate means of more advanced treatment and disposal methodologies must now be considered.

The theory of stream assimilation and stream quality standards has been at least partially negated by the new concept of effluent quality control–and efforts to achieve ever higher effluent quality regardless of the ability of receiving waters to accept effluents of different quality levels without tangible impairment of their safety and usefulness. Involved in this trend is the idealistic "zero pollution" goal which is explicitly implied in the 1972 amendment to the Federal Water Pollution Control Act. With increasing amounts of wastewater to be handled, and with mounting needs for water of usable quality to meet increasing demands, the concept of basing pollution control on assimilation limits alone can no longer be the policy of the States.

The pollution control concepts of the 1970's dictate that secondary treatment will be the required minimal treatment for both sewage and, in comparative value, for industrial wastes. Further quality improvement requirements are indicated as the Act's numerous deadlines are reached. The burden of proof is on the discharger of wastewaters, not on regulatory agencies; effluent monitoring and periodic reporting will be required standard control procedure.

The basic quality criteria for effluents now cover more than the standard factors of organic and bacterial standards. Serious concern is now aimed at nutrients which can become the contributors to eutrophication of lakes and other algae-breeding waters. The specific targets for elimination by treatment, or prevention by bans on use of products containing these chemical compounds, are phosphorous and nitrates. Land application techniques must now be evaluated on the basis of their ability to provide soil uptake of these eutrophication-producing substances as well as BOD, solids, bacterial and viral contents of applied effluents.

Still another category of contaminants is under serious surveillance: heavy metals and other toxic substances which could affect aquatic life and impair the safety of receiving streams for public water supplies and other critical uses. While these materials may be present only in trace amounts, their presence in effluents is viewed with such concern that the 1972 Act provides for pre-treatment standards for introduction of pollutants (for industries) into publicly owned treatment works (Section 307 (b) (l)); and for standards for toxic pollutants in effluents (Section 307 (a) (2)). The effects of toxic substances on effluent-irrigated crops, the ability of soils to retain such hazardous substances, and the presence of residual toxicity in groundwaters tributary to land disposal sites are matters of importance in evaluating the applicability of this method of disposal.

The discharge of treated effluents into receiving surface waters is an important means of balancing the flow of streams and augmenting lake water levels. Diversion of treated wastewaters to other watersheds other than the sources of the water supplies used by municipalities, industries and other users may be objectionable in cases where absence of this equalizing effect would be detrimental to the ecological balance of local waters. In some instances, the effluent from treatment works constitutes the total or major portion of seasonal flows in some streams. The principle of returning to the source waters the volume of flow taken from them, undiminished in quantity and unimpaired in quality, is the basic requirement of riparian rights to the use of natural waters. However, stream augmentation may take place from land irrigation through increased flows of springs or from the increased gradient of the groundwater table. It is important to note that land applications will not result in "zero discharge of wastewater" but may result in near "zero discharge of pollutants" into public waters, including both groundwaters and surface waters.

In some cases now, and in increasing numbers of cases when higher degrees of treatment and effluent quality will be required, the effluents returned to the streams may be of higher quality than the stream waters themselves. This adds significance to the concept of returning effluent waters to the watershed from which they were derived. Such effluents could have natural dilution value in maintaining stream flows and stream quality for highest classes of social usages.

Thermal pollution has become an important factor in stream management and aquatic environmental control. Wastewater effluents could be a factor in maintaining receiving waters within optimum temperature ranges for the spawning, propagation and life of fish and aquatic biota forms. On the other hand, the discharge of heated waters to streams, with their thermal pollution hazards, could be allayed by the spreading of such waters in land areas via holding ponds, spray systems and other means. Enhanced tree and fruit growth has been reported with the use of heated effluents from industrial processing or power production.

The use of heated effluents for improving aquaculture practices, such as the growth of catfish and small shellfish forms, has been recorded. This type of use, in the form of flow-through of effluents in fish ponds, does not necessarily deplete stream flows in the same way that losses due to evaporation-transpiration evolved from heated waters to land areas would—or as effluent use for land application purposes might. The factor of evapotranspiration of applied wastewaters on land and vegetation areas must be taken into consideration.

The current concept of land application as a viable alternative technique to wastewater treatment and discharge to surface waters involves the adequate treatment of wastes to produce effluents of relatively high quality for application to land areas. Thus, the degree of treatment for land application purposes might match the quality required for discharge into surface water sources. However, if advanced degrees of treatment for nutrient removal would be required to protect streams, lakes and coastal waters, application to the land could eliminate the need for such tertiary purifications.

Utilization of Effluents by Direct Recycling or Secondary Recycling and Reuse

Another alternative procedure for effluent utilization, in lieu of treatment and discharge to watercourses, is the treatment of waste flows to adequate degree—even ultra-treatment—and utilization of the effluent for industrial or commercial purposes. This technique involves the use of effluents for predetermined purposes because of the value of the liquid in various operations and because of its quality and the need for water which cannot be met adequately or economically from other sources. The utilization could be by direct recycling of safe and dependable effluents from the final stages of treatment and disinfection to the point or points of utilization. Or, it could involve indirect utilization by interposing an intermediate point of discharge and the ultimate use of the effluent waters, either undiluted or admixed with other waters.

In a sense, the discharge of effluents into bodies of water which are then utilized as sources of water supply for various purposes "downstream" from the point of discharge, represents a form of indirect utilization of these effluents for useful purposes. This follows the precept that there is no such thing as *new* water; that all existing natural waters have been used and, if of proper quality, are available for reuse.

The basic physical principle of non-destructibility of matter holds true in the case of effluent disposal. Thus, the discharge of effluents onto land areas results in the percolation of at least a portion of the liquid into the groundwater which can be tapped for useful purposes, or which eventually becomes part of the surface water flows to which the groundwaters are tributary, and which are then used in the same manner as "downstream" water containing directly discharged effluents.

Direct recycling of effluents for on-stream industrial use is standard practice, both in the case of sanitary sewage effluents piped to industrial installations, such as the Bethlehem Steel Company plant which uses activated sludge effluent from the Back Bay treatment plant of the City of Baltimore, or more recent examples of industrial use of effluents in other locations.

The direct recycling of effluents as potable water supplies has been advocated and practiced without great success or general public acceptance in one drought-ridden community in the United States, and with success in Wendhoken, South Africa. Recycled sanitary sewage effluents for limited uses, in multi-piping systems, has been advocated.

Two notable examples can be cited: Colorado Springs, Colorado, and Mexico City, D.F., have used separate distribution systems to convey treated effluent to widely dispersed areas within their jurisdictions. In both areas, the economics and availability of "unused" as opposed to "used" water made the project economically feasible.

The use of effluents as the source of fluid for recreational and aesthetic bodies of water, such as well-publicized recreational lakes in the Western area of the Nation, is a rational example of direct recycling of waters in an unbroken chain of utilization from water-to wastewater-to effluent-to useful water.

These are merely general examples of direct recycling and reuse of effluents. No attempt is warranted here to expand on this information because it is not cogent to the discussion of alternative methods of effluent disposal.

Indirect or secondary recycling of effluents is a form of disposal and reuse that lies somewhere in the area between direct effluent recycling and land applicaton techniques. This form of disposal is represented by several operations in the United States where effluents are discharged onto land areas in the form of percolation beds, seepage channels or other in-seepage devices, or actually injectioned into the groundwater table by means of wells or shafts. Operations of this nature are on record in the Western and Southwestern areas.

On Long Island, New York, where the only source of water supply is groundwater in the glacial till formations in Nassau and Suffolk Counties, large industrial use of water is regulated by state law which requires the return of on-stream flows back into the aquifers of Suffolk and Nassau Counties. In addition, actual injection of treatment plant effluent into the upper and lower aquifers of the two counties is under study. The use of injected water to allay encroachment of saline water from the Atlantic Ocean and Long Island Sound into the island aquifer is well known.

The use of effluents by either direct recycling or secondary, or indirect, recycling methods presumes that these effluents will be of a high degree of purity and dependability. Production of effluents of this quality requires secondary and, perhaps, tertiary degrees of treatment, supplemented by disinfection at unquestionable levels of bacterial kill.

The injection of effluents into groundwater sources involves other factors which go beyond so-called sanitary quality control guidelines. Studies conducted on Long Island disclosed, for example, that the presence of dissolved mineral or metal constitutents could clog injection well screens or cause clogging at the interface between the well shaft and the aquifer soils.

The high quality requirements for the disposal of effluents by means of direct or indirect recycling procedures preclude consideration of this type of disposal as a "quick and cheap" alternative to the types of treatment which present day practices and standards will dictate for water pollution control. Degrees of treatment would, at least in most cases, equal the requirements established under the provisions of the 1972 amendments to the Federal Water Pollution Control Act.

Application of Effluents to Land Areas

The application of effluents on land areas must be evaluated in the light of the mentioned factors on discharge into water sources or on the direct or indirect recycling of wastewaters. The applicability, feasibility and economics of land application must be ascertained in proper perspective with other means of managing effluent disposal.

If land application is an alternative procedure, the reasons for utilizing this technique offer various alternatives: (1) as a means of disposal without the necessity of constructing outfall lines to distant watercourses–the get-rid-of procedure; (2) as a means of improving the effluent by natural soil treatment and thereby avoiding the necessity of advanced treatment by conventional "artificial" processes; (3) as a means of augmenting the groundwater table; or (4) as a means of irrigating crops and improving yields in agriculture or silviculture. The land application installations investigated during the course of the current study cover examples of all these reasons for this method of effluent management, as well as other more or less valid purposes.

The ability of soil to remove organic pollutants by mechanical, physical and biological forces has been utilized in conventional sewage treatment methods, in the form of sand filters. Obviously, there is a direct relation between the artificial use of soil-wastewater contacts for treatment purposes and the application of effluents to natural land areas to "get rid of" wastewaters and to utilize the purifying capabilities of the soil to provide a form of physical-chemical-bacteriological improvement of quality.

Those early land disposal installations which applied untreated or only partially treated wastes to land areas were depending on the purifying capabilities of the land to provide "free" treatment. Today's concept of land application–and the basic definition of land application as investigated under the terms of the current contractual studies–involves the application of treated effluents of proper quality to assure the protection of the surface environment, groundwater, the use of crops grown on irrigated land, and the health and safety of on-site and off-site persons.

The movement of water on and through soil formations is a complex reaction which involves chemical-physical-biological reactions. Under proper soil conditions and control measures, improvement in water quality can occur during this movement. It can produce an effluent end product that is of markedly higher quality than the applied wastewater which has received the equivalent of secondary treatment by pre-irrigation means. This improvement is one factor that must be weighed in evaluating the applicability and workability of land application versus advanced degrees of treatment by other means.

The ability of soils to remove a major percentage of the nutrients in sewage effluents has led to the advocacy of land application as an anti-eutrophication procedure. If the transfer of effluent discharge from waters subject to nutrification and algal stimulation resulted in the mere shift from nitrates and phosphates in surface waters to their presence in groundwaters, less value could be attributed to land application methods. However, the mechanics of soil uptake and the utilization of such nutrients by plant life offer advocates of land application the valid argument that an ecological liability can be converted into an agricultural asset.

Similarly, the uptake of other potentially deleterious substances in effluents by soil mechanics represents another factor which must be weighed in placing land application in proper perspective with other methods of effluent management. These could include metals and chemical components which can be absorbed or adsorbed in or on soil particles or ingested by plant life. However, the effect of such chemicals on the soil composition and its friability and filterability, or on the safety of crops grown on such soils, must be considered.

References to the mechanics of soil management of effluent liquids and their quality improvement must be augmented by a brief comment on what has been defined as a "4-R cycle"–Return; Renovation; Recharge; Reuse. Liquid wastes are *returned* to the land by alternative means, including rapid filtration, spray irrigation, and other means of surface spreading. Irrigation can be accomplished by spray application, ridge and furrow flows and flood spreading.

Surface soil layers *renovate* the effluent by removal or conversion of pollution materials. The improved liquid is then used to *recharge* the groundwater. The renovated liquid is *reused.*

The land application process offers the possibility of meeting the conservationist goal of "returning to the soil that which came from it." The nitrogen cycle and the carbon cycle involve land in the completion of their reduction-oxidation-reconstitution sequences. If the organics in wastewaters and the chemicals of vegetative value, together with other exotic substances such as hormones, could be utilized to grow food from which the organics and other elements originally stemmed, the recycle of these materials by means of land applicaton would be achieved. For example, the *reuse* in the "4-R" concept described above, involves the reuse of not only the water component of wastes effluents but the nutritive composition of the liquids and trace element therein.

The land application technique, as an alternative effluent management procedure, must be placed into proper focus with other frameworks than specific engineering, technology and economics. The effect of setting aside large acreages for effluent treatment on the dislocation of farm dwellers must be considered as a sociologic-demographic problem of significance. The impact of land application on land use planning, zoning and long-range metropolitan-regional development must be considered. The effects on aesthetics are part of any thorough ecological evaluation of this alternative method of effluent disposal. Health and safety impacts must be considered.

Comparative costs of the various means of handling effluents, after suitable stages of treatment of municipal and industrial wastewaters, are difficult to compute and evaluate. They depend on such variable factors that no rule-of-thumb can claim to represent fiscal factors involved in any one specific project. These comparative costs must be placed into perspective with the goal of all-out elimination of pollutional discharges into the Nation's water sources, whether it be by degrees of advanced treatment which will provide "zero pollution" in direct effluent discharges, or the elimination of direct discharges by means of such alternative practices as land application.

No single answer could possibly become the panacea for all pollution control challenges in all areas. What may be the best and most economical solution for one region, one specific location, one actual wastewater flow, cannot be assumed to be the answer for another, even if superficial similarity can be found.

This is the reason why land application of effluents must be placed in proper perspective with itself, and with other methods of effluent management, in determining policies, practices and degrees of performance which will meet new and more demanding national standards of water resources protection and preservation.

EXHIBIT IX
Text Book Excerpt

"SEWERAGE AND SEWAGE PURIFICATION"

by

M. N. Baker, Ph. B. C. E.

Associate Editor, *Engineering News*

Broad Irrigation or Sewage Farming

Where sewage is applied to the surface of the ground upon which crops are raised the process is called broad irrigation, or sewage farming. The practice is in most respects similar to the ordinary irrigation of crops with clean water, the sewage being applied by a variety of methods, according to topographical and other natural conditions and the kind of crops under cultivation.

The land employed for this method of purification should preferably be composed of a fairly light, porous soil. The crops should be such as require, or at least develop best under, a large amount of moisture. Where the soil is heavy and wet, and the crops cannot stand much water, the sewage must be applied sparingly, and so a large amount of land and much labor must be provided. As broad irrigation areas may be prepared at comparatively small expense it is sometimes feasible to make use of land not so well suited to the purpose as might be desired, provided it can be obtained cheaply enough and too much stress is not laid upon the raising of crops. The less the attention paid to cropping, generally speaking, the greater the amount of sewage which can be put on a given area of land. Wet, clay soils can take but little sewage under any circumstances, but sometimes improve with cultivation and the application of sewage.

The application of an average of from 5,000 to 10,000 gallons of sewage per day to one acre of land is considered by many as a liberal allowance. On the basis of 100 gallons of sewage per head of population this means that one acre of land is sufficient for a population of from 50 to 100 persons. More could be purified if the crops would stand it, but for each kind there is a limit shich if passed means the destruction of the crop.

Allowing even 10,000 gallons of sewage, or 100 persons, to an acre in a city of 20,000 inhabitants would require 200 acres. To find suitable land at a low price near cities is not always easy. The larger the city the greater the difficulty. Labor, too, is a big item in sewage farming on this side of the Atlantic, especially near cities. As a partial offset to this, great cities afford excellent and never-failing markets. Another great obstacle to adequate financial returns from sewage farming in America is the deplorable fact that political ends and not business principles govern in large numbers of our cities, though there is good reaosn to predict a great change in this respect ere long. Where such conditions do prevail, however, the positions of both superintendents and laborers on sewage farms are almost sure to be considered rewards for and encouragements to party service, with results most unfavorable to the enterprise in hand. Sewage farming means the selling as well as the raising of crops, and perhaps of live stock, and so requires business ability and agricultural skill. The latter must be accompanied with the faculty of handling considerable bodies of men.

These apparently discouraging statements are meant rather as warnings. They are necessary because of the glowing representations which have been made regarding the profits of sewage farming by those who have not looked at all sides of the question. I am not unmindful of the results of sewage farming abroad, but European conditions are far different from ours. Many of the European farms are most admirably managed, both from an agricultural and business standpoint, and not a few of them have to contend with soil far less favorable than could be found in many sections of the United States. I do not say that an American city could not conduct so great an enterprise in a creditable manner, for we have found many well-conceived and well-operated municipal works of great magnitude. I do say that high prices for land near large cities, costly labor, a constant warfare against corruption with too frequent surrenders, and our sudden and complete changes in government all make sewage farming more difficult here than abroad.

For the present, sewage disposal cannot be accomplished in this country at a profit. It is sometimes possible to regain, through the raising of crops, a part of the expense entailed in removing and purifying sewage, and this is the only method by which any considerable portion of the expense has yet been recovered here or elsewhere. We should be thankful for the day of small things, and wherever a revenue can be obtained from irrigation area or filtration beds our efforts should be to secure it. But the logic of figures will often show that some method of disposal that carries with it no financial returns is the cheapest, in which case instead of crying over spilt and wasted sewage, we may laugh over a saving in capital, interest and maintenance.

Wherever irrigation, pure and simple, that is the application of water to crops for the sake of moisture, can be practiced to advantage, sewage farming should receive serious consideration, for in such localities every drop of water is valuable. As ordinary irrigation may yet be used in the East as well as in the West (it is already practiced to some extent in the South), the use of sewage for mere watering as well as fertilizing may some day be seen here and there throughout the length and breadth of the land. This is a subject which demands careful investigation and perhaps might be taken up with advantage by some of our agricultural experiment stations and by any live official in a position to do so.*

*For an article on "The Use of Sewage for Irrigation in the West" see *Engineering News* for Nov. 3, 1892; the substance of the article is also given in Rafter and Baker's "Sewage Disposal in the United States." A later treatment of the subject may be found in "*Sewage Irrigation,*" Nos. 3 and 22 of Water Supply and Irrigation Papers of the U. S. Geological Survey, by Geo. W. Rafter, M. Am. Soc. C.E. In March, 1905, the author of this book visited the sewage farm of Pasadena, Cal., and also land to which some of the sewage of Los Angeles is applied. As a result, he is more than ever convinced of the wisdom of using sewage for irrigation wherever water is scarce.

SECTION VIII
ACKNOWLEDGMENTS

The American Public Works Association is deeply indebted to the following persons for their services rendered to the APWA Research Foundation in carrying out this study.

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Special acknowledgment is given to the Texas Water Quality Board and the Department of Natural Resources, State of California, for use of bibliographic information supplied.

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SECTION IX

GLOSSARY OF PERTINENT TERMS

(as used in this report on land application of wastewaters)

Absorption – The process of incorporating water in the body of soil particles.

Adsorption – The process of attracting substances to the surface of soil particles.

Advanced Waste Treatment – A further degree of treatment of wastewater, over and above so-called secondary treatment, in order to further purify these effluent waters by the removal of additional amounts or types of pollutants, or their modification into non-polluting forms.

Amenable Industrial Wastes – Industrial wastewaters which contain no substances, or concentrations of substances, which could adversely affect sewer systems or inhibit the operation of sewage treatment processes which depend on biological reactions; amenability of wastes is improved when biological processes are replaced by physical-chemical methods of wastewater treatment.

BOD – Biochemical Oxygen Demand; a measure of the need for oxygen to satisfy the requirements of wastewater to stabilize its organic composition.

Climatic Zones – An arbitrary division of conterminous U.S. into geographical zones which have specific climatic characteristics in terms of seasonal weather, precipitation, humidity and other meteorological phenomena.

Conventional Wastewater Treatment – The removal of a large proportion of the contaminating materials in wastewater flows, or their chemical or biological conversion into stable forms, by use of physical, chemical, biological or other means or processes, in order to produce treated effluents that can be discharged into rivers, lakes or coastal waters without impairing the quality of these water resources.

Cropland Irrigation – See Supplemental Irrigation.

Eutrophication – The progressive enrichment of surface waters particularly non-flowing bodies of water such as lakes and ponds, with dissolved nutrients, such as phosphorous and nitrogen compounds, which accelerate the growth of algae and higher forms of plant life and result in the utilization of the useable oxygen content of the waters at the expense of other aquatic life forms.

Evapotranspiration – The process by which water or moisture withdrawn from the soil by plant life is evaporated or transpired into the atmosphere from the stomata of leaves and other surfaces of vegetation of all types.

Flood Irrigation – The spreading of wastewater over a broad area of land in the form of a sheet of varying depth, and the absorption or percolation of liquid into the body of the soil as it flows along a gentle slope of the land.

Flow Augmentation – The addition of water or wastewater effluents to surface water sources, for the purpose of increasing the volume of such waters as rivers, lakes or other inland bodies of surface water; in the case of groundwater, the addition of wastewater effluents which will increase the volume of the underground water source and raise or help maintain the groundwater table.

Friable – A condition of soil which makes it easily crumbled and powdery, as compared to becoming caked, hard and unworkable; a condition which could be induced by the accumulation of certain minerals or other materials in and on sand media.

Ground Cover – Any form of vegetative growth on land areas which will be used for the application of wastewaters; usually refers to low-lying vegetative forms which are left undisturbed on the land and not harvested, plowed under or turned over.

Groundwater – The body of water that is retained in the sub-soil of an area, as an underground resource which tends to move by hydraulic gradient to lower levels, often by outseepage into surface water sources in the natural drainage basin.

Groundwater Table – The elevation of the top of the groundwater contained in the underground soil; the groundwater table may rise and fall as the volume of water applied to the soil increases or decreases.

Holding Basin – A retention chamber designed to hold wastewater during periods when application to the land cannot be used, in whole or in part; the distinction between a holding basin and an oxidation pond is that the former may or may not be designed to provide any degree of treatment for the retained wastewater.

Hydraulic Barrier – A means of augmenting the groundwater volume and raising the level of the water table in order to create hydraulic gradients higher than the level of surrounding waters which would tend to inflow or infilter into the groundwater aquifer and introduce contaminants or other unwanted substances which could adversely affect its quality.

Land Application – The discharge of wastewaters onto land areas, as an alternative treatment procedure to conventional method and disposal of effluents into surface water sources.

Monitoring – A system of sampling of wastewater at various stages of treatment or application to land areas, and a regimen of testing and examination of these liquids to ascertain their quality and the presence of foreign or unwanted contaminating substances which might adversely affect the environment – land, water, air resources and its use by man, fish life and wildlife, or other forms.

Overland Flow Irrigation – A process of land application of wastewater which provides spray distribution onto gently sloping soil of relatively impervious nature, such as clays, for the purpose of attaining aerobic bio-treatment of the exposed flow in contact with ground cover vegetation, followed by the collection of runoff waters in intercepting ditches or channels and the return of the wastewater back to the spray system or its discharge into receiving waters; sometimes called spray runoff.

Oxidation Pond – A basin for the retention of wastewater, on a batch or continuous flow basis, where these wastewaters can undergo aerobic stabilization in the presence of adequate oxygen made available by various means of aeration, mixing, agitation or surface absorption.

Pathogenic Bacteria – Bacteria which can cause or transmit disease; in the context of this report, pathogens are bacterial forms which are water-borne and which can cause disease in those who come in contact with them via water, food, inhalation or other bodily contacts.

Percolation – The downward movement of water or moisture from the surface of the land down through the open spaces, or interstices, of the soil.

Physical-Chemical Treatment – A method of semi-advanced or advanced wastewater treatment which combines the use of chemicals, such as activated carbon or lime, to induce reactions such as coagulation, absorption or adsorption of pollutional substances, with processes which physically remove unwanted contaminants by such means as straining, screening, settling or filtering.

Population Equivalent of Industrial Wastewater – The caluculated number of people contributing sewage equal in strength to a unit volume of the wastes discharged into a sewer system, in terms of biochemical oxygen demand; a common base for computing the population equivalent is that one person contributes 0.17 pounds of 5-day BOD in the form of sanitary sewage per day.

Ridge-and-Furrow Irrigation – The application of wastewater onto land areas by ditches made by tilling or plowing or furrowing the soil into small valleys and ridges; the wastewater flows in the furrows and crop planting may be made on the ridges.

Riparian Rights – A principle of Common Law which requires that any user of waters adjoining or flowing through his lands must so use and protect them that he will enable his neighbor to utilize the same waters undiminished in quantity and undefiled in quality.

Secondary Treatment – Treatment of wastewaters by conventional means or processes, involving biological, chemical or physical means such as trickling filters, activated sludge and chemical precipitation and filtration.

Sewage Farming – A generic term relating to the disposal of sewage, in raw or partially treated form, onto farm lands for the purpose of utilizing the irrigation water and the organic nutrient materials therein for crop enhancement.

Silviculture – The nurturing and growth of trees and similar vegetative forms, as compared with agriculture, which relates to growth of grass, crops, food, feed and fiber.

Soil Uptake Capability – A measure of the capacity or ability of natural soils to absorb, adsorb, remove and/or modify such pollutants as phosphorous and nitrogen in wastewaters which percolate through such media.

Spray Irrigation – The application of wastewater to land areas by means of stationary or moving sprays which distribute the liquid in sheet, particle or aerosol mist form.

Spray Runoff – See Overland Flows Irrigation.

Supplemental Irrigation – The addition of water to land areas, by any means of application, to supplement natural precipitation, for the purpose of enhancing land productivity, sometimes called cropland irrigation.

Suspended Solids – Visible suspended matter in wastewater or other water which will settle out of the body of wastewater or float to its surface if allowed to remain quiescent; solid matter which can be removed from wastewaters by screening, settling or other means such as swirl action, centrifuging action or other hydraulic phenomena.

Toxic Metals – Any metal substances in wastewater which could be toxic or poisonous to grasses, to crops, or to groundwater, and which could adversely affect those who ingest or imbibe these substances; common examples of toxic metals are copper, cadmium or boron.

Transpiration – The process by which plants of all types of agricultural, horticultural and silvicultural growths dissipate water or moisture into the atmosphere from stomata of leaves or other surfaces, in the form of a vapor; dissipation of water by direct evaporation from the surface of plants, bark or other membranes, stomata, and lenticula into the atmosphere.

Underdrain System – A system of pipes or ducts, placed underground, to intercept and collect percolated wastewaters and to return these waters to a predetermined location for a predetermined purpose, often to prevent the discharge of such underground water into water sources which it is intended to protect.

Virus – Any of a group of ultramicroscopic, infectious agents that reproduce only in living cells; therefore considered evidence of human pollution.

Wastewater – Used water; municipal sewage or industrial wastes, or combinations of both wastes. (In the context of land application, wastewaters are considered to be liquid wastes which have been treated prior to application to land areas in order to assure the safety and efficiency of this process of effluent handling.)

Zero Pollution – A degree of pollution control or prevention which eliminates the addition of any contaminants or unwanted foreign material into surface water sources; incorrectly interpreted as "zero discharge" of any effluents into watercourses (land application of wastewater effluents has been suggested as one means of establishing "zero pollution" conditions.)

SECTION X
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APPENDEX A

QUESTIONNAIRE

CODE ☐☐☐☐☐☐☐☐☐☐ E

SITE INTERVIEW WASTE WATER LAND APPLICATION SYSTEMS

LOCATION (City-County-State) ________________ Report No. ________
NAME (Agency-Company) ________________________

FACILITY NAME ________________________

Land Disposal Facility Operated by (check) ☐ Owner ☐ Lessor
Lessor's Name ________________ Address ________________

A. COMMUNITY DATA

1. Population served by facility ________________
2. Population equivalent of waste (@ 0.17 lb BOD/d/cap) ________________
3. Wastewater treatment (check all applicable)

none ☐
primary ☐
secondary ☐
tertiary ☐
oxidation ponds ☐
effluent chlorination ☐
other (list) ________________

4. Sludge disposal

Treatment		Disposal Method	
Thickening	☐	Irrigation	☐
Digesting	☐	Tank Truck	☐
Filtering	☐	Spreading	☐
Drying	☐	Other	☐
Other	☐		

5: Average flow ________ mgd
Maximum system capacity ________ mgd

6. Combined sewer system ________ yes ________ no
Percent of system ________
Is stormwater treated? ________

7. For industry: Classification

canning ☐
milk ☐
refinery ☐
pulp and paper ☐
inorganic ☐
beverage ☐
other (list) ☐
organic ☐

B. LAND APPLICATION FACILITIES

Year first started ________

1. Wastes to disposal area by:

ditch ☐
pipe (gravity) ☐
pipe (pressure) ☐
truck ☐
rail ☐
other (list) ________________

2. Total area used ________ acres

acres irrigated ________
acres for buffer ________
acres for on-site storage ________
acres for on-site treatment ________
acres presently unused ________

3. Months of year used (circle)

J F M A M J J A S O N D

4. Average flow ________ mgd
________ lbs solids/day

5. Soil type:

loam ☐
silt ☐
clay ☐
sand ☐
gravel ☐
other (list) ☐

USDA/SCS Soil Classification ________________

6. Ground cover

Type	Acres	Annual Return to Agen.
________	________	________
Grass	________	________
Forest	________	________
Not cultivated	________	________
No vegetation	________	________
Crops (list)	________	________
________	________	________

7. Irrigation ________ days/week

Maximum application rate
______ in/hr ______ in/day ______ in/wk ______ in/yr
Average application rate
______ in/hr ______ in/day ______ in/wk ______ in/yr

8. Wastes applied by

spray (low pressure) ______ spray (high pressure) ______
tilling ______ other (list) ________________

9. Is renovated water collected? ______ yes ______ no

If yes, specify ________________

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10. Cost of land $ __________ per acre
Year purchased __________
Annual cost (if leased) $ __________
Term of lease __________ years
Value of land, est. 1972 $ __________ per acre
Value of adjacent land $ __________ per acre

11. Capital improvements:
Cost $ __________ Made __________ year
Cost $ __________ mgd

12. Zoning

	Facility	Adjacent Property
residential		
commercial		
industrial		
farm		
green belt		
other		

13. Distance to nearest residence __________ feet

C. OPERATION AND MAINTENANCE

1. Annual budget $ __________
2. Capacity of holding ponds __________ mg __________ acres
3. Treatment prior to disposal at site
aeration __________ chlorination __________
other __________
4. Is land leased for:
farming __________ grazing __________ (yes or no)
other __________
5. Security (check if used)
fenced ☐ patrolled ☐
accessible to public ☐ posted ☐
other (list) __________
residences on premises __________
6. Recreation use of site? If yes, specify
____
7. Any public health restrictions? If yes, specify
____

D. SYSTEM PERFORMANCE

1. Monitoring program
Test wells __________ number __________ depths

Item	Frequency/Samples
Influent	
Effluent	
Soil analysis	
Groundwater analysis	
Vegetation analysis	
Animal and insect analysis	

Other __________

2. Is system effluent:
reused __________ reapplied __________
discharged to receiving waters __________
lost to groundwater __________
3. Does groundwater interfere with system operation?
If yes, specify __________
4. Is data available concerning:

	Yes	No
buildup of N	☐	☐
buildup of heavy metal	☐	☐
buildup of chlorides	☐	☐
effect on plants	☐	☐
effect on animals	☐	☐
deterioration of groundwater quality	☐	☐
deterioration of receiving water quality	☐	☐
effect on water table	☐	☐
odors	☐	☐
health hazards	☐	☐

other __________ __________

5. Definite plans for future (check)
expand __________ continue __________
decrease (explain) __________
abandon (explain) __________
none __________
6. Is information available on:
Indicate yes or no:

Parameters	Influent	Effluent or Groundwater Discharge
BOD		
SS		
COD		
pH		
Fecal coli		
P		
Total N		
Nitrate		
Nitrite		
CL		

Appendix B
COMMENTARIES OF FIELD INVESTIGATORS

This Appendix contains the overall commentaries of the field investigators who inspected the land application sites selected for the survey program. These statements are selected and edited portions of the reports filed by the investigators to augment the fact-finding statistical reports. The commentaries do not cover all of the land application systems surveyed; the ones presented have been chosen because they provide an overview of the more significant evaluation items observed by the investigators.

These commentaries supplement the statistical data obtained during the course of the field visits. Their value lies in the "personal touch" nature of the information filed by the trained and experienced observers who performed the on-site investigations.

The accuracy of the observations is not here certified; they have not been checked in all instances with the public agencies and industries involved in the operation of the systems. The intent in presenting this information is to offer representative observations on the use and effectiveness of this method of effluent management.

For ease of reference, the reported date that each system was begun and the average flow to the land application facility is in parentheses following the name of the agency. Interviews are numbered to correspond with the questionnaire data listing of Appendix C in order to allow ready reference for additional data.

2. Lake Havasu City, Arizona (1971 - 0.55 mgd)

Lake Havasu City is a development of the McCulloch Company. The area about the city is desert land. The wastewater irrigated lands, including the golf course land and the adjoining airport, are Federal lands made available to the Sanitary District. These are not straightforward, single-item leases, so no lease cost could be computed.

McCulloch Properties and the Sanitary District shared the costs of the pump equipment and pipe for getting the water from the holding pond to the golf course and the costs of the holding pond. Shared cost for each in 1971 was about $14,000.

The Sanitary District plans to expand water uses as increased effluent becomes available for the second nine holes which will be built on the golf course, some city park facilities, and highway median.

The golf course pays $20/acre-foot for effluent for about 30+ acre feet per month. Domestic water sells for $75 for the first acre-foot and $40/acre-foot thereafter.

3. Mesa, Arizona (1957 - 4.3 mgd)

Mesa has one wastewater treatment plant and delivers about 3 mgd to the Phoenix plant. The Mesa plant serves a flow of 4.3 mgd.

The Phoenix plant receives most of Mesa's industrial wastes, so that the influent to the Mesa plant is nearly 100 percent domestic sewage. Capacity of the pipeline to the Phoenix plant is 10 mgd which will be reached by 1980. Mesa must either expand its existing plant, building another plant of its own, or construct as a joint venture a new plant with the City of Tempe. Tempe will reach its present plant capacity before 1980.

All of the Mesa plant's reclaimed water is used for irrigation. The only present alternative is to discharge it to the dry riverbed where it would percolate into the groundwater.

Mesa presently has pending a HUD open space application for a 1,000-foot greenbelt around the plant site which would be watered with reclaimed water.

8. Las Virgenes Municipal Water District (- 3 mgd) Calabasas, California

Calabasas presently uses, for agricultural irrigation, almost all of its 3 mgd of secondary treated effluent. Twentieth Century Studios uses reclaimed water for "greening" outdoor movie and TV sets. These uncultivated grounds are used as a disposal area when excess water exists. The plant is not permitted (by WPCB) to discharge to Malibu Creek, under a restraining order, as the creek discharges to the ocean at a recreational beach area.

The plant operator indicated that the effluent presently meets drinking water standards.

Twentieth Century also uses effluent to fill a "tank pond" as a setting for lake or ocean films. A painted backdrop serves as background with model ships used for filming. "TORA, TORA, TORA" was filmed on reclaimed water.

Reclaimed water is provided in a pressurized hydrant system in part of Malibu Canyon for fire-fighting purposes.

There is no groundwater of acceptable quality in the canyon. There are only three wells--TDS ranges between 1,500-3,000.

Fish from the holding reservoir are edible. The Fish and Game Department has done extensive testing.

Potential uses for reclaimed water that are actively being pursued are:

1. Watering of one and maybe two golf courses several miles away and high in the canyon.
2. Irrigation of landscaping on Pepperdine College campus at lower end of the canyon near the beach.
3. Implementation of a dual water system in the areas suited for potential development - a domestic water supply inside each home and a reclaimed water supply for landscaping, irrigation, car wash, etc., on the exterior of each home.

11. Dinuba, California (1954 - 2.4 mgd)

No crops are raised at present because the former plantings of grapes and plums were over-aged and had to be removed. No money was available for plant stock so agriculture is now abandoned. However, the land application is conducted just as it was for the former plantings - ridge and furrow. There are tentative plans to create a game reserve on the property.

The sandy soil at the site which is flat is conducive to ready absorption of high application of effluent. Inasmuch as lab facilities have yet to be installed, technical data are meager.

12. Fontana, California (1971 - 2.3 mgd)

The 2.3 mgd flow receives only primary treatment by the City of Fontana. All flow is used for irrigation of three types of crops:

(1) Citrus - 72 acres
    Five-year contract for 360 acre feet/year (1971-1975)
(2) Hayfields
    Informal agreement - irrigation and disposal 27-acre parcel - irrigating 17 acres
(3) Grapes - 20 acres
    Two applications per year before blooms on grapes - 10 mg/year

Flow to citrus farm - mg/month:

June 1971	18.5
July	25.8
August	22.0
September	19.5
October	15.3
November	11.4
December	6.7
January 1972	6.6
February	6.3
March	12.7
April	13.7
May	15.9
June	15.7
July	18.2
August	11.8

The citrus farmer is very happy with use of reclaimed water. This is the first complete year that it was used prior to the trees' blooming period. No other fertilizer is used. The leaf growth is larger and there is more of it and the fruit is larger and more plentiful. He indicates that he likes the continuous feeding by the effluent nutrients vs. twice-a-year fertilizing that is normally done. Also he is using about twice as much water as when he was irrigating with domestic water. Before using reclaimed water he bought about $7,000 of domestic water per year for irrigation at $20-21/acre foot. The reclaimed water is free, with the City paying pumping costs. He used approximately the equivalent of $14,000 worth had he bought domestic water.

The City makes no charge for the water – it is only concerned about disposal. All water goes on the land. There is no discharge to receiving water. They used to percolate water, but had reached maximum percolation capacity and had started irrigating with the idea of selling it for a profit. It did not work. They now irrigate as a disposal method.

Figure 13, Fontana, California, contains photographs of the holding pond and irrigation facilities used.

13. Fresno, California (1891 - 50 mdg)

The wastewater plant is on a site originally operated as a "sewer farm" without treatment in 1891. It has evolved to include primary treatment to the bulk of the sewage with oxidation ponds and about 15 mgd of secondary treatment. New headworks facilities are under construction and 200 additional acres of land are under acquisition. Gradually, land has been withdrawn from grazing to construct additional oxidation ponds.

At one time, the grazing area was sown to forage crops but that has not been done for some years and at present there is an indiscriminate growth that supports some cattle. There is some consideration being given to discontinue grazing and merely till the disposal area periodically.

There is a comprehensive system of concrete-lined distribution canals complete with weirs and diversion gates convenient to the flooding of the diked pasture areas. Odorous conditions are prevalent; however, there probably is not much nuisance from this source as the surroundings are completely agricultural.

14. Hanford, California (1900 - 2.5 mgd)

This was a well conducted operation, apparently very successful. Plans include purchase of more land for expansion. As the primary duty of the land is to receive effluent, the farming enterprise must accept what the City delivers; however, that practice has only caused minor problems to the farmer. The land is in a game reserve area and although the farm area is not fenced, there are no serious trespass problems.

The planting during the present year was to oats, cotton, and a hybrid corn used in milling a tortilla flour. Crops looked excellent.

16. Rossmoor Sanitation, Inc.
(1964 - 1.4 mgd) Laguna Hills, California

There are four major disposal sites (in order of priority for the reclaimed water):

1. Golf Course - 125 acres - Sprinkled 340,000 g/d ann. ave.
2. Lion Country Safari, water for San Diego Creek wild animal water holes, and some irrigation - 100,000 g/d
3. Irvine Company up to 1,000 acres of "field and forage" crops. First year for this use. 1.1 mgd intermittent use over seven-month period. Flood irrigation.
4. Greenbelt - 295 acres. Under flight path to the El Toro Marine Air Station. Sprinklered. Part of Rossmoor property.

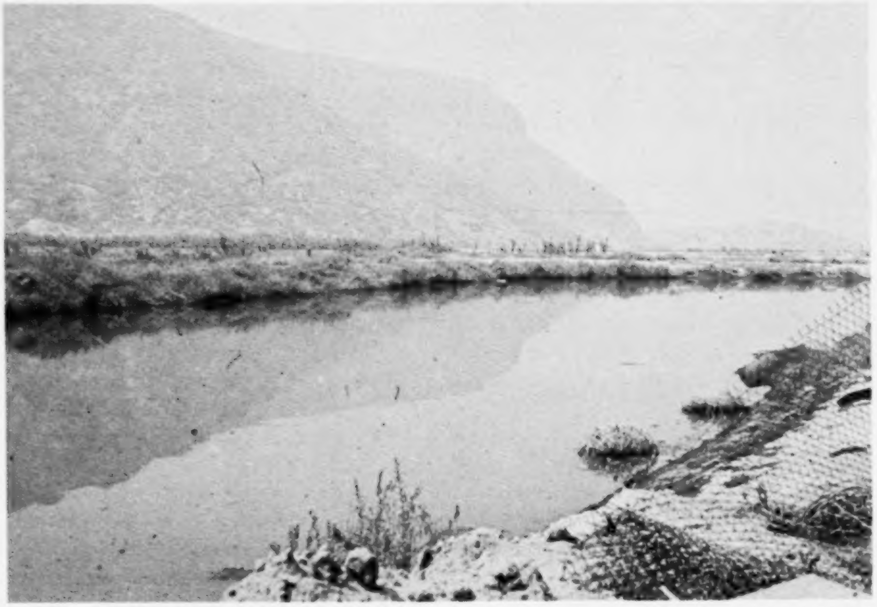
All effluent water is used on these sites. It was not determined precisely how the farmer (Irvine Company) is applying the water or the precise amount of acreage being irrigated. It is done on the basis of the farmer's judgment as to water need.

The water is sold to the golf course for $47/acre-foot. Domestic water sells at $78/acre-foot. The water is free to Irvine Company since it serves as a disposal method. There are no other alternatives available for disposing of the water.

At the plant, four small ponds are maintained to determine the effect of aerator and chlorination levels, as well as to determine effect of effluent on fish and small wildlife.

17. Livermore, California (1965 -)

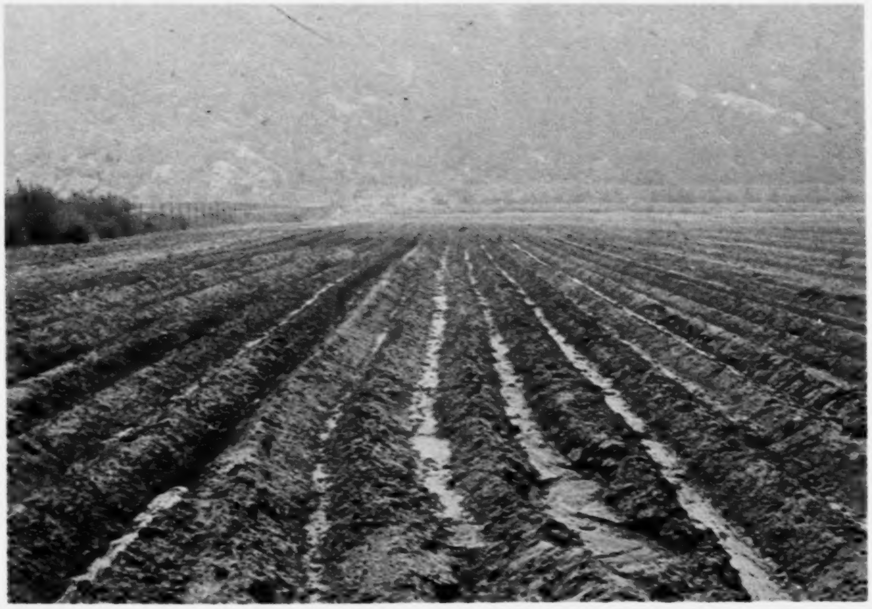
This facility is well organized. The effluent is used on the airport landscaping and



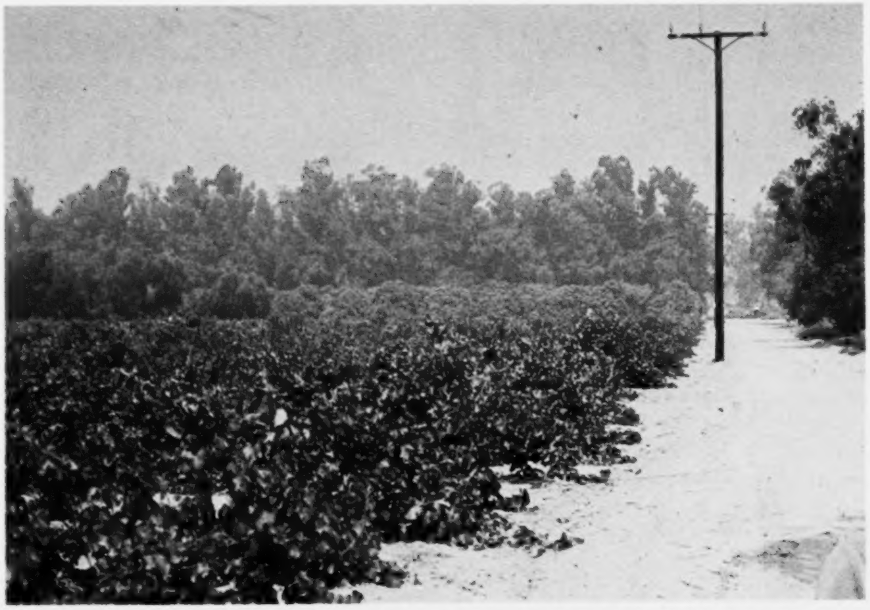
a. The 1.5 acre, 1 mg capacity holding pond

b. Irrigation land

FIGURE 13
FONTANA, CALIFORNIA



c. Ridge and furrow irrigation in former hayfield



d. Irrigated vineyard in foreground; in background are irrigated citrus trees and a windbreak of eucalyptus trees

FIGURE 13
FONTANA, CALIFORNIA

90 acres of alfalfa on the airport site, for the city-owned golf course, and on an adjacent farm for irrigation of about 200 acres of row crops. Surplus water flows into Las Positas Creek, thence to the Niles cone area where it mingles with other imported water to replenish an overdraft of the cone.

The farm irrigation diversion is allowed without payment to the City as long as surplus water is available. There are other potential public uses being given consideration which might well develop in the future. These include expansion of park facilities adjacent to the site and irrigation possibilities on the freeway interchange which is close by. There is a series of ponds on the golf course served by the effluent disposal system and the site is traversed by Las Positas Creek which is the drain for excess flow.

In sum, all of the effluent from the facility except that lost by evaporation is conserved for beneficial reuse.

18. Lodi, California (1944 - 3.7 - 5 mgd)

The City of Lodi is surrounded by a vigorous agricultural community which produces a seasonal fruit processing and canning industrial load to be handled by the community. The flow from the canneries is conducted to the plant site by a separate line. Screening is required at each processing plant so that there is no gross evidence of the wastes.

Cannery flow may be treated with the domestic flow or distributed by means of irrigation ditches directly to the several pasture plots. These plots are flooded successively in an operation conducted by the tenant cattle raiser.

The plant and pasture operations are located on a single, city-owned site adjacent to White Slough, one of the myriad branches of the Sacramento-San Joaquin Delta System. The land is level and only a few feet above tidal elevation. It is underlain by brackish water unsuitable for domestic water supply. Unused effluent may be discharged into White Slough, which is generally only a winter occurrence.

The plant and pasture lands are very well kept and present an overall excellent appearance.

19. Irvine Ranch Water District (1968 - 2.8 mgd) Irvine, California

All effluent water is reclaimed for agricultural uses. The plant has no other alternative disposal means. The plant is prohibited from discharging effluent to the adjoining flood control channel because it ends up in Newport Bay (Pacific Ocean) which has a major recreational use.

Attempts to retain water in ponds for private duck clubs were resisted by the Public Health Department because the plant could not maintain the low coliform count demanded - mpn less than 2/100 ml.

The Irvine Company is concerned with the amount of salts in its irrigation water. It wants less than 1,000 ppm of salts for agricultural uses. It is blending or alternating the effluent water with matching amounts of Colorado River water.

The plant estimates an average flow of 40 mgd by the year 2000. It has negotiations under way to expand its reclamation uses of the water to include: (1) an 18-hole golf course, (2) 50 acres of landscaping on the University of California at Irvine campus, and (3) ornamental irrigation on 25 acres of a County Regional Park with ultimate expansion to 200 acres.

20. Oceanside, California (1957 - 1.5 mgd)

Originally, the plant disposed of the effluent by percolation into ponds in the riverbed. Recharging of the groundwater was important to halt saltwater intrusion. Flow was pumped seven miles inland from the plant to a holding pond, then by gravity flow to percolation ponds.

The City leases the 40-acre holding pond area, a 40-acre spray disposal area, and the percolation pond areas from an adjacent property owner for 200 acre feet of reclaimed water per year. The City has usually exceeded that amount. The water table has since risen (1969) so that little percolation occurs. Now the City uses the farm ground for disposal as well as irrigation. The percolation ponds washed out in a 1969 flood.

Since the water table filled, water is discharged to the river, but the State Water Quality Board is concerned about the high nutrient value of the water. The City is under a cease and desist order. It submitted plans 14 months ago for enlarging and upgrading the land application system. Only the emergency outfall system portion has been approved.

The farm area that is irrigated varies over the year from 150 acres to 400 acres, with an estimated annual average of 250 acres. The City is also using 40 acres of floodplain area that is covered with vegetation, but not cultivated, for waste disposal of water. Water is sprayed on the disposal site seven days per week. Ten acres are sprayed at a time for a period of 4 to 5 days, 24 hours per day, followed by 12 to 15 days of drying time while the other 30 acres are sprayed.

Expansion plans for using reclaimed water include: a contract ready for signature with State Division of Highways for 600 acre-feet/year to irrigate freeway. City put in rapid sand filter and chlorinator and pipe to the freeway. Capital costs amortized over 20 years and annual filtering and pumping costs charged to State - estimated at approximately $50/acre-foot. Also plans for 125-acre and 400-acre County Regional Park. Other possible agricultural uses include a strawberry farm.

22. Pleasanton, California (1957 - 1.3 mgd)

This is a well conducted operation both as to treatment and disposal and would likely be satisfactory if there were only moderate growth likely. However, the community is growing rapidly and plans are under way to provide a multicommunity sewer system for the valley and commitment has been made by the City to join the system when complete, which is expected to be in about five years.

The irrigated area is essentially level and sprinklers apply water consecutively to all parts. There is a slight rise adjacent to the irrigated area where cattle can be quartered when the fields become somewhat soggy during inclement weather. This is done to protect the forage cover from excessive cattle-tromping damage.

The land is leased from the City of San Francisco which owns it as underground water reserves. The yearly lease cost is $12,900; no profit is made on the City's grazing operation.

Inasmuch as the operation is conducted over an important underground aquifer, regular groundwater sampling is conducted by California State Department of Water Resources.

23. Santa Maria, California (1935 - 4.8 mgd)

The City of Santa Maria operates a secondary treatment plant followed by oxidation ponds. The entire flow of 4.8 mgd is conveyed by ditch to a 155-acre pasture partly owned by the City and partly leased. Under the terms of the lease, all water must be used.

The City is looking for alternate disposal methods as the plant expands. Water Quality Control Board wanted a $200,000 pipeline that would discharge chlorinated effluent into the Santa Maria River that would carry it to the ocean. The Water Resources Agency denied the plan - the City must keep the water on the land. The City is considering an alternative to buy additional land for percolation ponds.

25. Santee County Water District
(1959 - 1 mgd) California

Effluent water is presently percolated into a spreading basin below oxidation ponds. It surfaces downstream in the river channel and is used for recreational lakes (boating, fishing), then flows to the golf course where it is picked up and used for irrigation. Some water flows on through the golf course.

The value of the water was established at $50/acre-foot three years ago. Domestic water sells for $59/acre ft (was $19/acre ft 10 years ago)

Potential uses of additional water are freeway watering, and possible new agricultural areas on a greenbelt in the usually dry riverbed.

It appears that the basin in which Santee is located has been filled with percolated effluent water (most all domestic water is imported - Colorado River water). This water is surfacing at the lower end of the basin and flows to the ocean in the river channel.

The County Health Department has stopped approving tentative tract maps and has issued a cease and desist order to Santee, claiming that the nutrients in the water have promoted dense brush growth to the point that it cannot provide an effective mosquito abatement program.

Several land application uses are made of the effluent after it has passed through the recreational-use lagoons. These uses include sprinkling of the golf course and tree farm.

Figure 14, Santee, California, contains photographs of portions of the system.

27. Golden Gate Park (1932 - 1 mgd)
San Francisco, California

When the park was built in the 1870's, there was no adequate water source. Two well fields were developed and raw sewage was diverted from the Lincoln Avenue sewer to a septic tank. It used the combined well water and septic tank effluent to irrigate the western half of the park.

In 1931, a suit was brought that forced the abandonment of the septic tank. A 1-mgd activated sludge plant was built near Elk Glen Lake. The effluent served as irrigation water along with the well water for the western part of the park until 1947. At that time, a pumping plant was built at Elk Glen Lake to serve the eastern part of the park.

Water Reclamation Plant

The Water Reclamation Plant, placed in operation in 1932, is a conventional activated sludge plant without sludge treatment. Primary sludge, grit, and screenings are returned to the sewer that connects to the Richmond-Sunset Plant.

The effluent quality is good, with suspended solids around 10 mg/l and final effluent mpn less than 2.2 per 100 ml. The effluent form of nitrogen is mostly ammonia although nitrification occurs periodically. In early 1972, the effluent suspended solids began to increase and the mixed liquor suspended solids were reduced from 1,200 mg/l to 200-300 mg/l. The chief operator suspects that the composition of the sewage is changing due to the activity of several research hospitals in the area.

Irrigation System

About 800 acres of the park are irrigated by fixed sprinklers, supplemented by hand sprinkling. Irrigation is usually required from April to October, but in some years irrigation has been required until December. The water reclamation plant generally operates from mid-February until November and produces about one-third of the water for irrigation of the 800 acres. Irrigation usually lasts for one and one-half to three hours with an application of about 1 inch of water. The resting period is usually six days. The calculated loading rate for this sandy soil is 3,750 gpd per acre, or about 1 inch per week.

Groundwater does not interfere with the irrigation practice and no test wells have been drilled. The well field in the western part of the park is declining with only three of the original seven wells still producing.

30. Woodland, California (1889 - 8.7 mgd)

Sewage farming in Woodland began in 1889, with the irrigation of hay and pasture land east of town. In 1905, the resultant odors led to a lawsuit that forced the sewer farm to be moved. From 1905 to 1930, farming with sewage continued in a larger tract east of the original plot. The City has purchased additional land over the years so that it now owns over 1,400 acres.

In 1948, a primary sewage treatment plant was constructed on Beamer Street, with the effluent being used for irrigation. The City has built numerous ponds since that time and now all treatment except coarse screening is accomplished in oxidation ponds.

The present municipal waste flow is 4.2 mgd and the tomato canning waste averages 4.5 mgd from mid-July to October. Near the abandoned primary plant a series of ponds provides the equivalent of primary plus secondary treatment for 0.3 mgd which is then percolated into the ground. A flow of

1.75 mgd is piped directly to a larger ponding area while the remaining 1.45 mgd is treated in primary ponds at site 1, treated in secondary ponds at site 2, and discharged to the irrigation ditch. At the second pond site, the 1.75 mgd is provided primary and secondary treatment in ponds and discharged to the irrigation ditch. This is accomplished in four ponds of 12 acres each. An additional 0.7 mgd of municipal wastewater is piped from the southern area of Woodland directly to this area and is treated in four ponds of four acres each.

Adjacent to this second pond site are 320 acres for the treatment of the canning waste. These ponds are very shallow and some odors are produced. The total area of this second pond site is 800 acres. The soil is an adobe clay with a pH of 11 and is very high in sodium. This material was deposited as a part of old lake beds and is quite distinct from the neighboring arable soil.

The irrigation ditch runs eastward to a site near Tule Canal in the floodplain of the Yolo Bypass. The City owns 430 acres which are presently leased. The lessee also owns and irrigates 240 acres of milo north of the City's land. This year, he raised safflower (a nonirrigated crop) on the City's 430 acres. He pays the City $10,000 a year for the land and has the right to the treated effluent when he needs it. On the 240 acres of milo, he applied 30 inches of water at a rate of about 1.5 inches per week. The water is applied by flooding and the runoff is collected in a drainage ditch which discharges into Tule Canal.

The Regional Water Quality Control Board's requirements for discharge to Tule Canal are a minimum of 60 days' detention prior to discharge and a dissolved oxygen content of 5.0 mg/l in Tule Canal. When water is not needed for irrigation, the 430 acres are flooded and leased as a duck hunting area. Parts of the 320 acres of industrial waste treatment ponds are also leased for duck hunting.

31. Colorado Springs, Colorado
(1953 - 4-7 mgd)

The City of Colorado Springs, after severe droughts in 1953, initiated a limited program to water municipally owned grassed areas with wastewater treatment plant effluent. Severe watering restrictions placed on all residents had previously resulted in the loss of large grassed areas.

The present system is divided into two lines. The western line is composed of a pressure line to an abandoned water reservoir from which the effluent is again pumped to the facilities to be irrigated. These include a median strip where an old gravity irrigation system was previously used for flood irrigation of the wide median strip, Colorado College, and a new, exclusive country club area, "Kissing Camels." The latter area has its groundskeeper personnel water the golf course and the lawns of numerous high-class residences on the grounds.

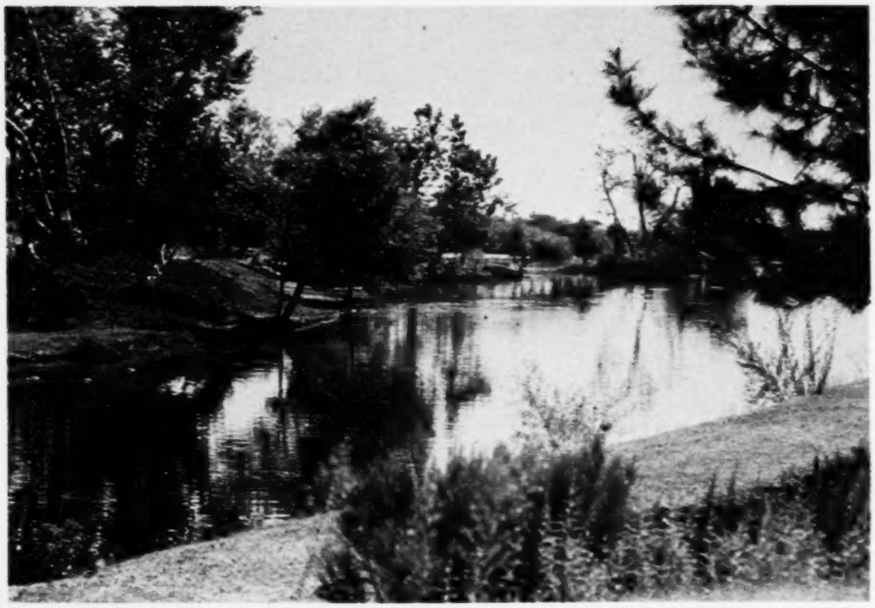
On the pressure lines, a series of fire hydrants has been located, painted a distinctive blue and white color. These fire hydrants may be used by contractors who can utilize the low quality water for purposes such as construction and tree watering. An annual fee is paid. In addition, the Fire Department may use the lines in an emergency.

The eastern line is pumped to an abandoned water reservoir from which, by gravity, several facilities, including a cemetery, park, a private development (Printers Union Home and Office), and a golf course are watered.

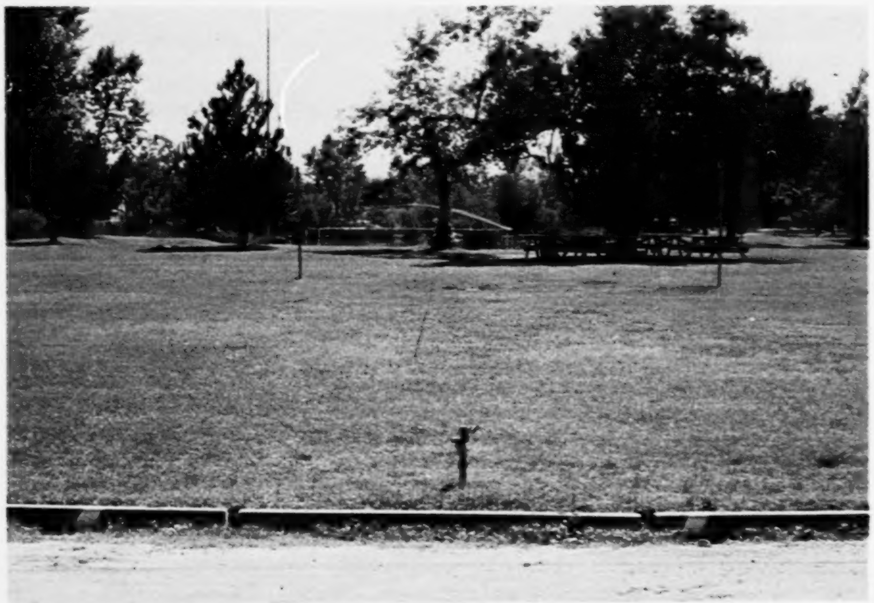
The system has been designed to provide water for irrigation along the Interstate Highway System. Although the State Highway Department participated in the cost of one of the pressure lines, it has not used the system

Figure 15, Colorado Springs, Colorado, contains photographs of portions of the system.

Private customers are charged a rate of 10 cents per thousand gallons plus pumping, which averages approximately 14 cents per 1,000 gallons. The 1969 sales were $24,090; 1970 sales $36,815; 1971 sales $36,598. In 1971, tertiary treatment was added. Flows for irrigation are subjected to either physical-chemical treatment process or sand filtration. The cost for new sales of water will

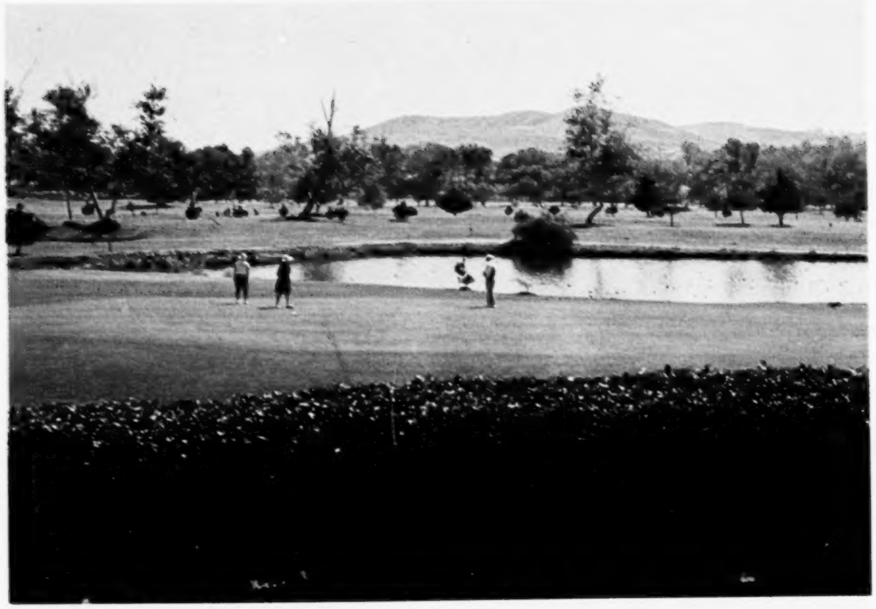


a. Recreational lakes

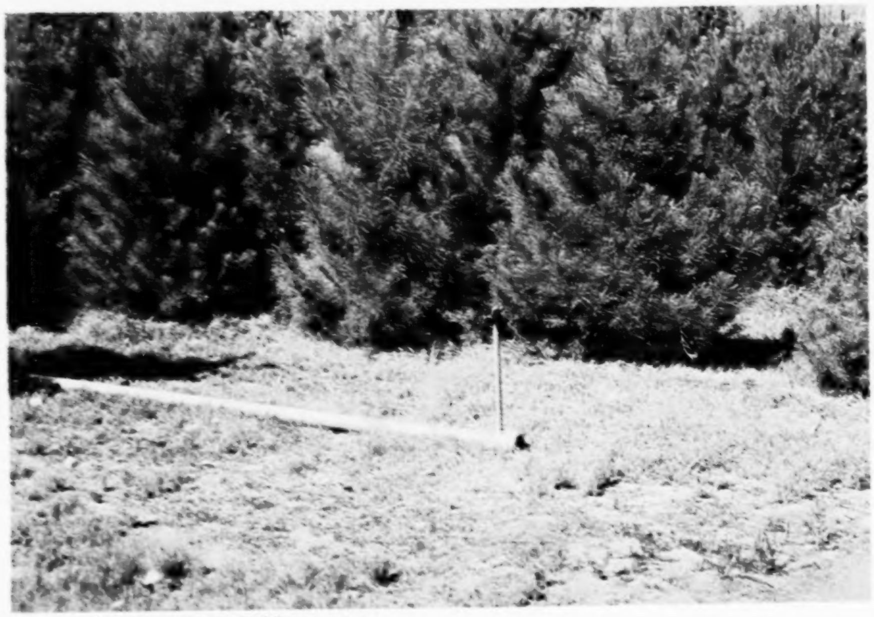


b. Sprinkler system in park

FIGURE 14
SANTEE, CALIFORNIA

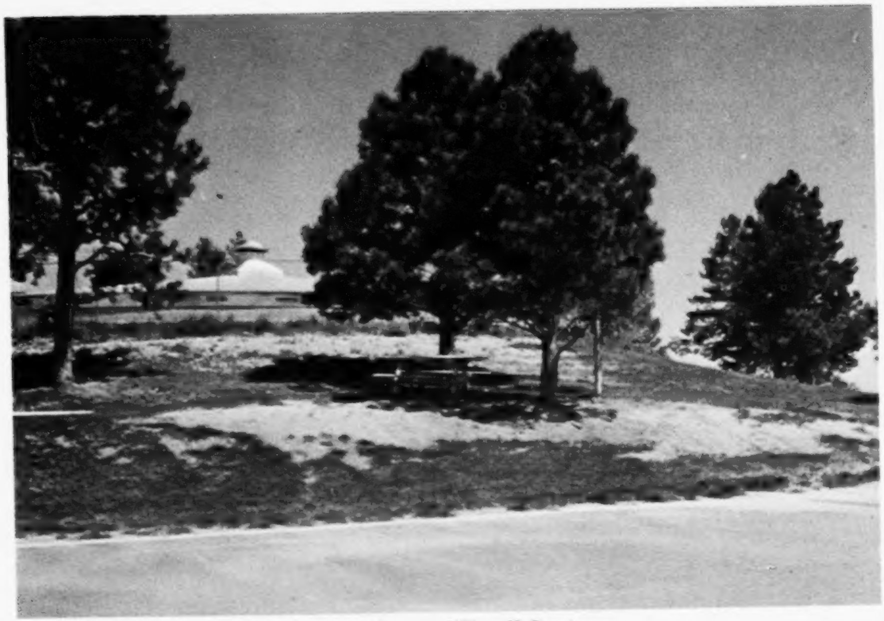


c. Golf course and holding pond

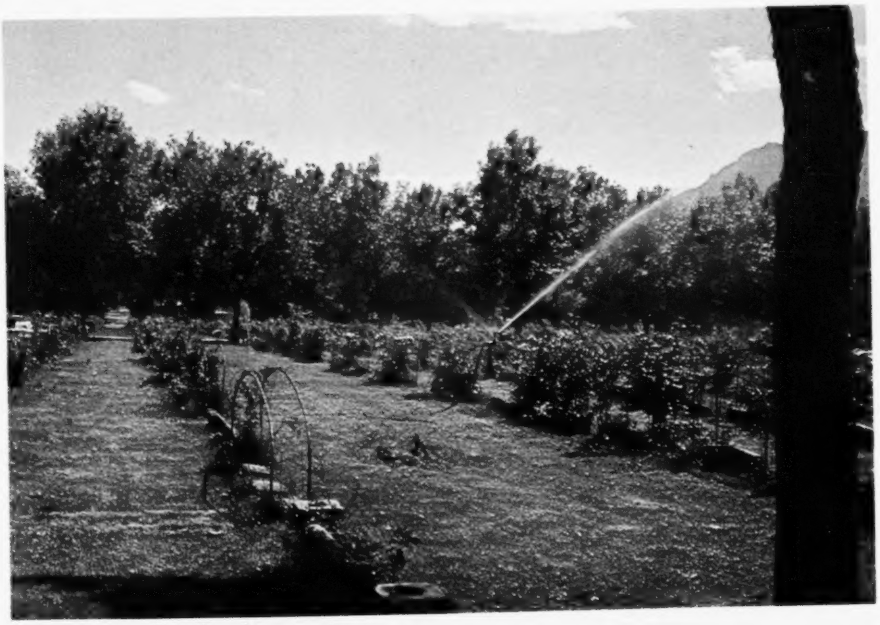


d. Tree farm with sprinkler system

FIGURE 14
SANTEE, CALIFORNIA

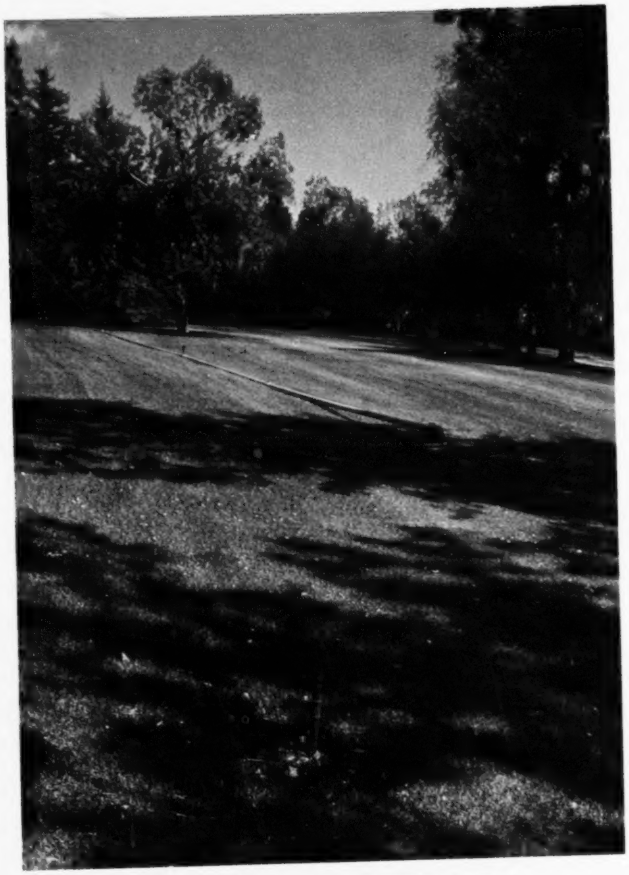


a. Covered storage water reservoirs on "East" System



b. Spray application in cemetery

FIGURE 15
COLORADO SPRINGS, COLORADO



c. Portable distribution system at ITU Home (side)

d. Spray irrigated park (below)

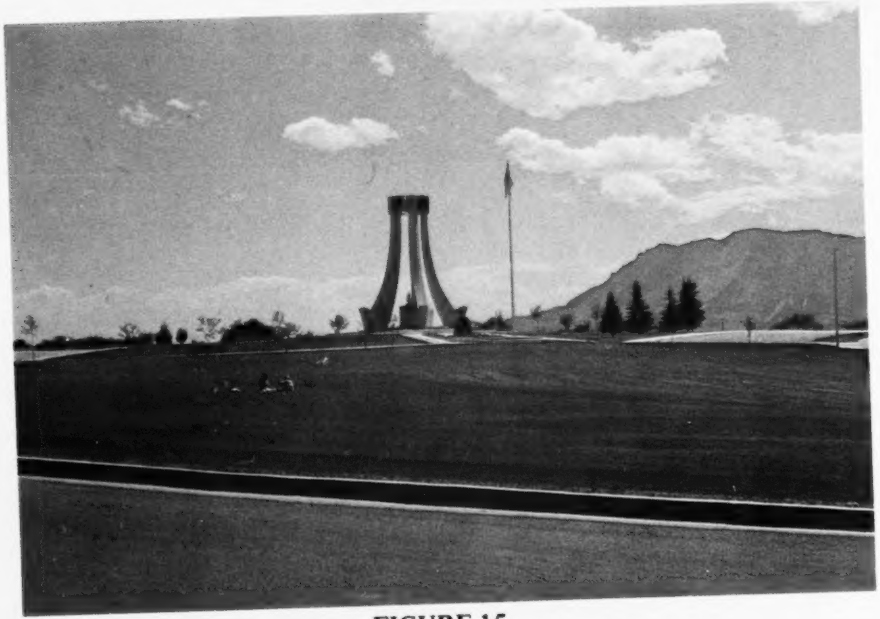


FIGURE 15
COLORADO SPRINGS, COLORADO

be 30 cents per 1,000 gallons, plus pumping.

The operating cost by the City for the irrigation operation was: 1969, $42,965; 1970, $34,197; and 1971 with tertiary treatment, $137,689.

The reservoir on the west section is open to the public and public fishing is allowed. On public properties, in accordance with Colorado State regulations, some signs exist pointing out that a nonpotable water source is used for watering. On public property, either underground sprinkler systems or portable aluminum pipe systems are used.

Some odor complaints have been received by the City when the reservoirs have been allowed to hold water for several days because of rain. The entire system is operated on the basis of demand for watering and the water is taken only as desired by the users.

During 1971, 336 million gallons were treated by the tertiary plant. Two hundred three were used for irrigation and 133 for industrial use.

The area of facilities watered on the east line includes the Wastewater Reclamation Plant, 27 acres; Evergreen Cemetery, 206 acres; Memorial Park, 115 acres; ITU, 50.5 acres; Lunar Park, 3.4 acres; Otis Park, 2.4 acres; and Patty Jewitt Golf Course, 235 acres. On the west line: Colorado College, 55 acres; Parkways, 2.3 acres; Acacia Park, 3.7 acres; and Kissing Camel Golf Course, 82 acres.

The cost of the improvements to the western line was $62,000; to the eastern line $196,890; and for tertiary treatment $1,054,000.

32. Disneyworld, Florida (1972 - 1.5 mgd)

Tertiary treated domestic effluent is applied to a sandy, 100-acre demonstration plot. Approximately half of the area is planted to grass and the other half to trees. A 6-acre plot of ornamental trees and 46-acres of eucalyptus trees are being grown. The eucalyptus are being grown for pulpwood. Preliminary tests indicate that heights of 25 feet can be achieved in two years' time, starting with a 3-inch sapling. USGS, on a cooperative project, has installed test wells to determine groundwater elevation. A minimum of other control tests is planned; however, the dosage rate at 2 inches per acre per week is considered low enough to assure that the system will not be stressed.

A development cost of $100,000 was incurred for clearing 160 acres of land. Holding ponds and pumps were not included.

33. Okaloosa County Water and Sewer District (1972 - 1 mgd)
Fort Walton Beach, Florida

As a result of observing the application in Tallahassee, Trustees of the district decided to try land application. The contact stabilization wastewater treatment plant was opened in 1972.

From the plant, effluent is pumped 16,000 feet to an 80-acre tract on Eglin AFB. The area is covered with scrub pine and natural forest growth. Application rate is governed on a trial and error basis. Until September, each of three 8-acre plots was irrigated for 12 hours and then rested for 24 hours. Because of ponding, each plot is now watered in series for six hours.

Local plans appear to be to clear the land. Local water supplies are from 700-foot wells. There is a perched water table at 40 feet. State prohibits discharge of effluent to receiving waters without 90 percent BOD removal.

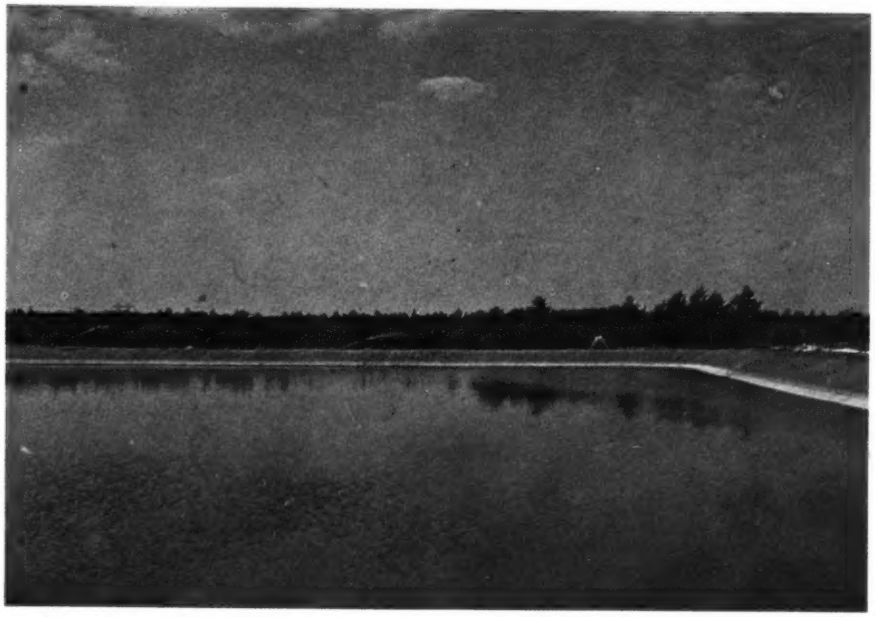
The spray system is designed to operate at 62 psi, and to deliver 47.8 gpm over a 172-foot diameter. Maintenance involves one visual inspection per day.

It was reported that all local governments are planning to install land disposal systems - press reports from Eglin estimate that 7 mgd will be applied to AFB land.

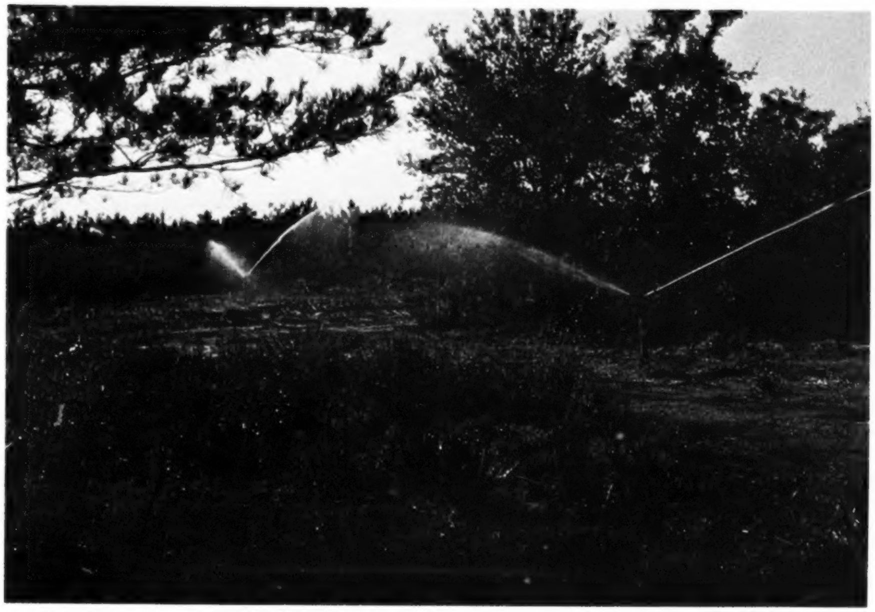
Figure 16, Okaloosa County Water and Sewer District, Florida, contains photographs of the application area on Eglin AFB.

34. St. Petersburg, Florida (1972 - 0.16 mgd)

The City of St. Petersburg has a 4-acre plot on which it is attempting to determine the feasibility of land application of wastewater in urban areas. The test site was

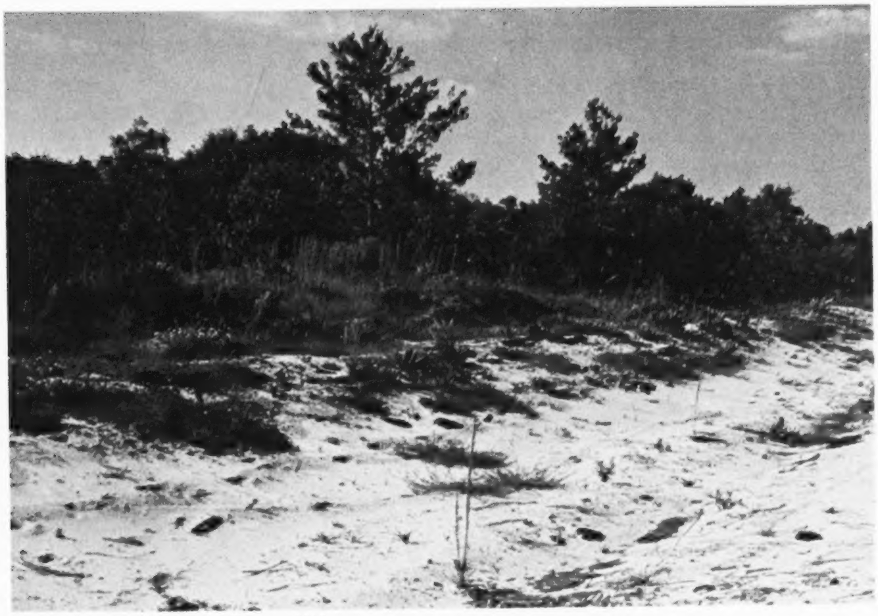


a. Holding pond – 8 acres



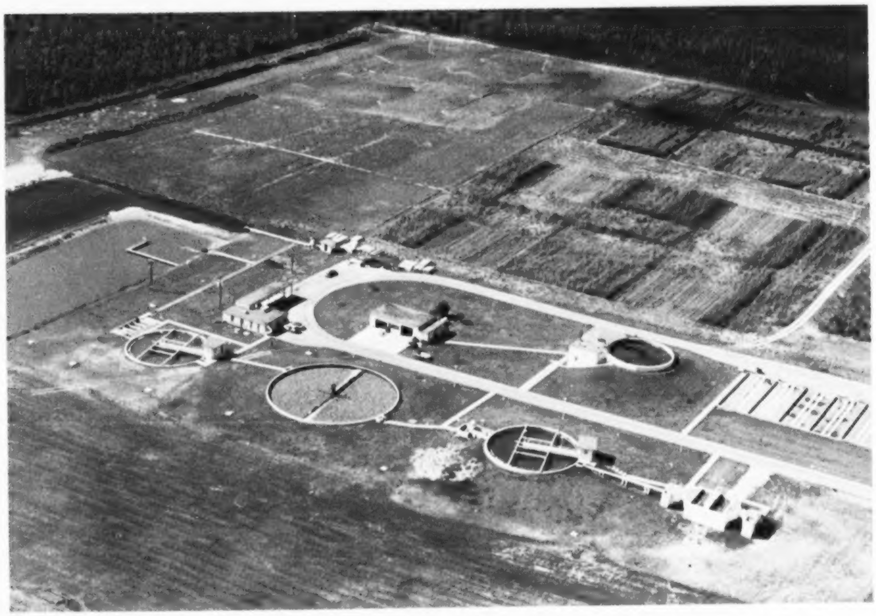
b. Fixed spray heads in scrub forest area

FIGURE 16
OKALOOSA COUNTY WATER AND SEWER DISTRICT, FLORIDA



c. Natural sandy soil conditions

FIGURE 16
OKALOOSA COUNTY WASTES AND SEWER DISTRICT, FLORIDA



Aerial view of treatment plant and crop experimental area.
Forested area at left is irrigated with two large water cannons.

FIGURE 17
TALLAHASSEE, FLORIDA

started in March 1972 and consists of a series of wells and fixed sprinkler heads on a plot in close proximity to the existing treatment plant. Pump capacity is about 1 million gallons per day to this site.

Preliminary estimates indicate that perhaps 25 percent of the moisture will be lost through evaporation and plant transpiration, 50 percent will follow a clay layer at a 5-foot depth and flow into a lake, and 25 percent will penetrate the clay.

The City of St. Petersburg has made proposals to OWRR and to USEPA for a research program to determine public acceptance of the concept, identification and movement of viruses, and other factors related to the large-scale demonstration project. The hope is to minimize the use of domestic water for irrigating golf courses, parks, and other large-scale developments.

35. Tallahassee, Florida (1966 - 2 mgd)

The present 2.5 mgd plant was built in 1965 and disposal has been by land since 1966. In 1972, 20 acres of forest land were put under irrigation. Prior to that, all effluent went on a 16-acre plot of grasses and crops. The disposal area is on low sand hills of marginal forest land.

Wastewater discharge at Tallahassee is presently 8.5 mgd. By 2000 A.D., it is estimated that the City will be treating 20 mgd. At present, about three-fourths of the secondary effluent flows to Lake Munson, west of the City. About 2.5 mgd is treated at the Southwest Wastewater Treatment Plant, where all the secondary effluent is contained on the plant site. Plans are now being formulated to increase the size of this facility to 10 mgd to meet expanding needs. It is planned to retain all discharge on the land, possibly through sprinkler irrigation, in response to increasing pressure against lake pollution.

Four plots are presently served by sprinkler irrigation. The system is constructed to serve four subplots for each plot, each subplot being served by four sprinklers on a 100-foot square arrangement and providing an application rate of 1 inch per hour. This system, which has functioned satisfactorily for five years, provides four application rates for each crop. Data may thus be obtained on yield response, efficiency of nutrient removal, and forage quality simultaneously for four crops. Application rates used during the 1970-71 year include winter rates of 1/2, 1, 2, and 4 inches. Soil samples are taken from each subplot to measure changes in potassium, calcium, magnesium, pH, and salts for each crop and each treatment. Feeding trials are conducted with forage receiving the heaviest application rates using beef cattle. Analyses here include intake levels, energy content, and total digestible nutrients.

Figure 17, Tallahassee, Florida, is an aerial view of the wastewater treatment plant.

Every effort is being made to stress the system, that is to apply a maximum amount of irrigation. During June 1972, test plots were watered at the rate of 2, 4, 6, and 8 inches per week and at the same time applications determining the effect of watering at one application as opposed to spreading out the watering over the week. Definite improvement in yield and crop growth is shown with the higher applications. The difference between weekly and more frequent watering is not readily apparent.

The total application is deemed successful and a plant expansion which will take place this year will provide up to 10 mgd. This will be applied on land adjacent to the plant. Carryover spray is considered to be a problem and screen planting is strongly urged along roadways.

The land is flat; depth to groundwater 35 feet; annual evaporation 55 inches.

One test well is 2,500 feet downstream; tests from it have not indicated Cl, N, or bacterial contamination.

Plans for the future include forest clearing and using coastal bermuda and winter rye as crops.

Phosphates appear to be well fixed by the soil.

The application rate to the forest land is 200,000 gal./acre/day.

State now prohibits discharge to receiving waters of effluent with less than 90 percent BOD removal.

36. St. Charles Utilities, Inc.
St. Charles, Maryland

St. Charles is a new community in Charles County, Maryland, developed as a private utility, constructed using a Federal government guaranteed Title IV New Community Loan as administered by HUD. Building started in 1966. The sewer system and disposal facilities, consisting of treatment lagoons and spray irrigation areas in wooded areas, now serve 1,500 residences, a population of about 6,000, and a sewage flow of approximately 0.5 mgd. This is an example of a new, planned community utilizing spray irrigation as a means of sewage disposal, in lieu of conventional treatment facilities.

Choice of land application, following lagoon treatment of raw sewage, was made with the approval of the State Department of Health, rather than discharge into surface waters. No rivers or other streams were available for this latter purpose; an interceptor to the Potomac River would have entailed a run of some 5 to 6 miles at a cost of some $17 million, and requiring many years of planning and construction. An initial proposal to discharge effluent into Zekiah Swamp was rejected after a public hearing and serious complaints from property owners in the new community. The State Health Department demanded an alternate proposal and the consulting engineers recommended spray irrigation of lagoon effluent.

This decision was based on availability of undeveloped land in the 8,000-acre St. Charles Utilities plot; the presence of wooded areas which could receive spray effluent; and the sandy nature of the soil which would provide adequate drainage, absorption, and discharge to groundwater that is approximately 5 to 6 feet below grade. The surrounding area did not pose any problems of groundwater contamination for nearby properties. The State apparently imposed no requirements for sewage treatment or effluent quality, over and above what could be achieved by lagooning of raw sewage delivered to the site from in-town pumping station facilities.

Choice of spray irrigation into wooded areas, with no intended crop production or tree-growth benefits, was based on the utility's need for the cheapest disposal means. Spray irrigation was intended as the disposal method and no possible revenues or benefits of spray irrigation were considered in making the decision to use the system. Standard sewage treatment and disposal of effluent into the Potomac or a tributary stream thereto would have involved secondary treatment processes and effluent chlorination. The cost factors led to the irrigation decision.

The land value is now $2,500/acre, approximately, but the land was available in 1966 as "spare" acreage, with no immediate community growth planning that would have made the land used for sewage lagooning and spray irrigation more valuable for residential-commercial development. Present plans for development of an industrial park area in the St. Charles Utility complex still do not affect the economic rationale for spray application of effluent. Zoning restrictions were not a factor in irrigation.

At this time, the Charles County Sanitary Commission is planning to construct an interceptor and treatment works for the entire region, with possible completion in 1980, and St. Charles would at that time discontinue its lagoon-irrigation system and discharge its sewage into the regional system.

The State apparently made no firm requirements on degree of treatment or effluent quality as standard criteria were not available. The State did, according to the consulting engineers, approve the method of treatment and of effluent disposal. Monthly effluent analyses by a private laboratory indicate the following: suspended solids 25 to 50 ppm; BOD 50 ppm; D.O. 6 ppm; pH 7.0. No analyses of coliform content are reported. No analytical monitoring of groundwater quality is reported.

Whether soil permeability tests were carried out is not clearly indicated. However, the sandy nature of the soil was evident during the inspection. The ground is flat.

Climate is moderate. It is reported that freezing weather may be encountered for brief periods - say one to two weeks - followed by milder temperatures. This provided for year-round irrigation, with only short periods of holding of effluent in the lagoons, followed by resumption of spray irrigation before the holding capacity of the lagoons is exhausted. By lowering the depth of the lagoons in the fall, room is provided for holding when necessary. The dikes around the lagoons provide holding volume.

The original acreage of the lagoons - 10 acres - has been doubled to 20 acres. The irrigation area covers 35 acres, in nine fields covered by separate spray systems which are operated independently. Design provided for control of spray fields by hand-operated valves. Spray distribution headers are 6-inch aluminum pipe, with 2-inch laterals upon which are mounted 3/4-inch to 1-inch risers serving a small number of stationary spray heads and, mostly, rotating sprays of Rain Bird or equal manufacture. Effluent is pumped to the fields from two separate stations at approximately 40 psi at the nozzles. Piping is at ground level.

Design was based on one acre of irrigation area for each 50 homes and one acre of lagoon area for each 75 dwellings. The initial criteria limited spray application to two inches per acre per week. There appears to be lack of consistency in application rates, with some data indicating double this rate. Application varies with the nature of the soil and the percolation rates.

No buffer zone requirements were specifically required by the States, but adequate buffering is provided by the secluded nature of the utility-owned plant site and the total St. Charles' 8,000-acre development.

The distance to the nearest structure (a historic Episcopal Church and church cemetery plot and an adjacent home) is approximately one-half mile; the distance to more densely populated areas is approximately one mile. The church may utilize a well for water supply but no record of analyses was available. The area is posted for "no trespassing" but no specific reference is made to the use of the land for irrigation purposes. Seclusion, rather than positive protection, is depended upon.

Rates of spray application apparently vary from 1/4 inch to 1/2 inch per hour, and 1 inch to 2 inches per day, based on four hours of spraying, followed by shutdown of the dosed area and transfer of the effluent to another area by means of manually operated valves. The four-hour spray period was observed by the investigator during his visit, with the shutdown occurring at noon. The annual dosage evidently ranges from 50 inches to 100 inches per year, indicating resting of each area for four to some seven days between applications, depending on soil drainability and weather conditions.

It was reported that forest mulch has been left undisturbed in the spray areas because this organic mat induces better drainage. An effort to clear one area resulted in flooding and washout of the soil. Some weak underbrush was noted in the spray area, but no dense growths were reported and no efforts to keep brush in cut condition were needed or utilized. Operating personnel, as noted during the inspection, include one supervisor and three employees engaged in handling the lagoons and spray fields, part time.

No observations were reported to determine whether tree growth is greater in the irrigated area. The attitude is: Our job is to get rid of the sewage, not to seek any profit from irrigation practices.

The aluminum effluent distribution piping and the spray nozzles have functioned satisfactorily. Routine maintenance has sufficed. The 6-inch lines are designed to "weep" or drain when pressure is released, thus providing protection against freezing during cold weather.

Pretreatment is by stabilizing lagoons, utilizing three consecutive ponds in series for each of two separate lagoon systems. The first pass is aerated, with two mid-lagoon aeration units; a third will be installed in each of the two systems. The lagoons have never been cleaned but floating scum and aquatic growths are skimmed or flushed down with water hoses, using lagoon water and a portable wheeled pump unit. The effluent from one of the systems contained evidence of heavy eutrophication on the day of inspection; the other was not so affected. Odors from the aerator in the eutrophied system were fairly heavy; the other system was not odorous. No significant *psychoda alternata* populations were observed. The lagoons showed evidence of *archorutes*, or springtail growths, floating on the surface of the sleek that was blown to one end of the water areas by prevailing winds.

Soil clogging in the irrigation fields was minimal during the observations. Some clogging was reported by the staff, but this was not considered of importance because the fields recover their porosity when rested. The spray area is flat and there is no evidence of surface runoff of the applied effluent. No protection is required to prevent runoff.

Cost of operation and maintenance is reported by the consulting engineers to be about $1,000 per month - or $0.06 per 1,000 gallons. Annual costs were reported as $12,000 to $15,000 per year for the lagoon and spray irrigation area, including labor and electric power for the effluent pumps.

The cost of construction of the system was reported by the consulting engineers to have been $1,100 per acre of irrigation area.

37. Forsgate Sanitation, Inc.
(1967 - 0.4 mgd) Cranberry, New Jersey

Forsgate Sanitation, Inc., is a subsidiary of the Rossmoor Corporation, developer of the town of Rossmoor, New Jersey. Rossmoor is a comprehensive, new town concept for persons age 52 and over, and provides planned housing and recreational facilities for middle- and upper-income retired persons. Rossmoor was started in 1967 and originally was planned to include 20,000 dwelling units. Construction has not proceeded as rapidly as originally estimated, and only about 1,100 units have been constructed to date. Additional units are presently under construction. The recreational facilities include an 18-hole golf course.

When the new town of Rossmoor was started, Forsgate Sanitation, Inc. was created to provide water and sewage treatment facilities. The treatment and disposal system was designed to serve 20,000 dwelling units and is therefore being operated at a fraction of its capacity at present.

Land application was chosen over stream discharge on the basis of economics and esthetics. Stream discharge would involve construction of some two miles of discharge line estimated to cost about $500,000. Land application at the Rossmoor golf course involved a discharge line of about the same length but construction was cheaper since Rossmoor controlled the right-of-way. An added bonus for land application was the provision of water for two artificial lakes on the golf course and a source for irrigation water for the golf course. The disposal system is designed to provide infiltration from the lakes since the spray irrigation schedule is controlled by the golf course and depends on local rainfall conditions. A similar disposal system is planned in conjunction with a 36-hole golf course which is being built to serve another large housing project in the area.

Treatment

The treatment plant consists of primary, secondary, and tertiary treatment facilities. After secondary treatment, the filtered effluent is pumped to a storage lagoon of about 13.5 million gallon capacity located adjacent to the treatment plant. Some natural oxidation occurs in the storage lagoon which also supports an abundance of fish and other aquatic life.

Effluent from the storage lagoon is pumped back through the treatment plant for tertiary treatment consisting of rapid sand filters (Hardinge type) and chlorination. Effluent from the tertiary treatment is then pumped to the two artificial lakes at the Rossmoor golf course.

Disposal

The 18-hole golf course is an integral part of the Rossmoor residential development and is surrounded by houses. Two artificial lakes on the course are supplied by treatment plant effluent. The combined area is estimated at about 6.6 acres. The two lakes were constructed by excavation to a depth of about 7 feet and are lined with an impermeable plastic liner except for a perimeter infiltration zone. This arrangement allows the water level to remain reasonably constant even though irrigation demands are not consistent.

Water overflowing the plastic lining percolates down to groundwater through an underlying stratum, locally known as "sugar" sand.

At the time of this visit, the lakes were clear and completely odor free, with no evidence of algae or aquatic plants. Fish, muskrats, and other aquatic life were reported plentiful in the two lakes. A producing water well, located some 300 feet away from the two lakes, is tested every 60 days, with no adverse results reported.

38. Landis Sewerage Authority and City of Vineland, New Jersey (1901 - 1.2 mgd)

This evaluation covers both the City of Vineland, New Jersey, sewage treatment and effluent disposal system and the facilities of the Landis Sewerage Authority. Both installations are parts of a single community and augment and supplement each other. The sewage flow handled at the City's treatment and land application project does not reflect the size of the City and its industrial installations. A system operated by the City itself serves the old inner core of the community, sometimes known as the borough. The Sewer Authority owns and operates the sewer system, treatment plant and land application facilities which serve the larger outer area of the City.

This unusual condition is the result of the way the community was first developed and subsequent growth of the City into what is described as the largest municipality in south-central New Jersey. The City of Vineland operates a Municipal Utilities agency which supplies water and municipally generated electric power to the entire City. The sewer system is, however, not integrated.

The City of Vineland sewer system was installed prior to, and up to 1901, at which time the original treatment plant and land application system was built. The treatment plant consisted of a septic tank which was modified in 1927 into a somewhat more modern covered septic tank provided with sludge draw-off piping and valves which utilize the hydrostatic head of the septic tank contents. The original concept of land application of the primary effluent to broad irrigation basins, utilized in the 1901 system, was continued when the plant was reconstructed in 1927.

Land application of the effluent was chosen as the cheapest method of handling wastewaters. It eliminated expensive outfall facilities into suitable water resources points and followed the so-called standard practice of discharging septic tank effluent into the soil by means of subsurface leaching lines or pits. It must be remembered that the year was 1901, according to city records, and that modern sewage treatment processes were not known or practiced. When the treatment plant was modified in 1927, the "success" of the broad irrigation method over the quarter century of years probably led to continuation of this method of effluent disposal.

When the Landis Sewerage Authority built its sewage disposal plant in 1949, it was not surprising that land application was chosen as the process, in view of the continued use of this system by the City of Vineland. The two treatment plants and two broad irrigation fields or basins are located on adjoining sites. Whether the State Health Department approved of the Landis installation, and of the earlier city installation, was not made clear to the investigator. What is known, however, is the fact that the State is now demanding more advanced degrees of sewage treatment and better assurance that land application is not affecting groundwater quality, both from the City and the Authority.

In the meantime, the City of Vineland contends that it is not operating a sewage treatment plant, which by State Law is defined as a facility that discharges effluent into public waters (and makes no reference to groundwater as public waters).

Land for the two treatment and disposal facilities was readily available. Zoning was not a problem because the area is basically agriculture in nature, with residential development of secondary importance at the time the City and Authority took necessary acreage for sewage works purposes.

No consideration was given to utilizing the nutritive value of effluent for crop-growing or silviculture purposes. Vineland officials reported to the investigator, however, that for several years a local farmer obtained permission to plant corn in a portion of the broad irrigation area. He stopped this practice because of thievery of his crop, indicating that public entry to the area was possible. No crop-growing experiences were reported at the authority site.

Design Factors

Pretreatment at the Landis Authority plant involves an attempt at aeration of raw sewage and plain settling of the flow in mechanically cleaned rectangular tanks. In brief, primary effluent is broad-irrigated with no apparent ill effect on the soil media. However, as indicated, the State is now requiring upgrading of the Landis plant to probably secondary treatment effluent, with chlorination, and assurances that the groundwater quality is not being affected. The plan now is to reconstruct the authority plant to meet state requirements and to abandon the city plant when the City's flow is delivered to the authority system.

In order to meet deadline schedules of USEPA and the State, the Authority adopted a Resolution on February 25, 1972, stating that it would provide new treatment facilities capable of reducing the organic loading at the plant by 90 percent and removing nitrate nitrogen so that the groundwater withdrawn from the water table 500 feet in any direction from the irrigation area will meet New Jersey potable water standards. Pre-treatment of industrial-commercial wastes will be required by the Authority to eliminate all toxic substances and reduce nitrate nitrogen to a maximum of 10 ppm.

The soil available for irrigation is sand. The land is flat and no effluent runoff is possible. The irrigation beds are fully diked.

Broad irrigation was designed for year-round operation. Some freezing of the bed areas was anticipated but the degree of freeze-up was considered unimportant; operation has confirmed this anticipation.

No use of groundwater by nearby property owners was contemplated in the original designs of both the city and authority irrigation facilities.

The following land use data are available:

ACREAGES	CITY OF VINELAND	LANDIS SEWERAGE AUTHORITY
Total site area	170 acres	100 acres (Estimated)
On-site treatment plant	2	4
Irrigation facilities	30 plus	40 plus (Estimated)
Unused site land	135 acres	50 (Estimated)

Vineland treats approximately 1.2 mgd, of which 80 percent is sanitary sewage and 20 percent industrial-commercial wastes. The Authority reported average flows of 4 to 5 mgd; during peak canning season, the sanitary flow and industry flow is about 50-50. During off-peak periods, the sanitary flow may be 60 or 65 percent and the industry wastes flow may be 35 to 40 percent.

During the inspection, the effluent at Vineland was red colored due to the preparation of bottled beet soup (borscht) at the Manischewitz processing plant. The authority effluent was milky in appearance. Odors were surprisingly low at both plants, despite the septic tank used at the city installation.

Operation and Maintenance Procedures

Method of Effluent Application: At both sites, effluent is discharged onto the irrigation beds through short riser pipes at one end of the flooded area. No operation problems were reported.

Rate of Application: Irrigation basins are flooded from depths of a few inches at shallow ends, to some 18 inches at deepest points. No efforts are made to level the beds. It may take one to two days to fill a basin. The basins are then shut off by closing gates and allowed to drain, a process requiring a week or more, depending on soil clogging, precipitation, temperature, etc.

Land Cover: The sand beds are natural native soil. The basins were not specially prepared, nor are they underdrained. When the basins are drained dry, they are disced or harrowed (sometimes they are shallow-plowed) to turn any sludge coating under the soil. No sludge is removed. Clogging of the basins has not been experienced, surprisingly, after years of reapplications.

After the beds have been cleared and prepared for reuse, they are again dosed, as needed, to maintain a predetermined cycle of irrigation for the plant effluents. Both the city and authority irrigation practices are alike.

Groundwater Monitoring: The city irrigation system has no monitoring wells. The Authority has installed some wells, equipped with liquid level gauges to indicate groundwater table variations. No water quality sampling is provided, to the best of the investigator's knowledge. No soil analyses are undertaken.

39. Alamogordo, New Mexico (1963 - 2.5 mgd)

Alamogordo is a city of about 25,000 located in a desert region near Holloman Air Force Base and the White Sands Missile Range in southern New Mexico. Annual rainfall in this area is 8 to 10 inches.

The City of Alamogordo has, since 1963, sold its sewage treatment plant effluent to a farmer. All of the effluent, 2.5 mgd, is used to farm 260 acres growing alfalfa, corn, oats, and sorghum. The City is paid 20 cents per year per water meter in Alamogordo. This amounts to approximately $1,400 annually at this time.

The City plans to abandon the existing plant and construct a joint facility with Holloman Air Force Base. The new plant will have a capacity of 6 mgd. The effluent from the new facility would be used to irrigate parks and city-owned agricultural land.

40. Clovis, New Mexico (1927 - 3.5 mgd)

Clovis is a city of about 30,000. Many cattle are raised in the vicinity of Clovis and Swift has a meat packing plant there. The average rainfall in this area is 17 inches per year. Some crops can be grown without irrigation but most farmers are irrigating to improve their yield.

Clovis is located in a basin which has no outlet. All the rainfall collects in the low areas and ponds. The ponds are called playas. The treatment facility is adjacent to a playa and all of the effluent from the plant empties into the playa. All of the storm water from the City also is ditched to the same playa. From the playa the farmer that owns the surrounding land, 1,150 acres, pumps the water through an underground system to the fields where it is discharged into furrows to run through the crops. The tailwater is collected in a reservoir and pumped back to the field crops. No water is lost. The playa was about 40 acres in size in September, but varies with the season and weather. The playa has no odor problems. The farming operation is very efficient and two crops are grown on some of the land. In addition to raising crops, the farmer grazes cattle and leases land to other ranchers for grazing. The cattle drink the water from the playa. There is no apparent bad effect on the animals.

41. Raton, New Mexico (1950 -

Raton is a city of 6,500, located in northeastern New Mexico. Sewer service is available to only 2,300 people at this time. The effluent from the sewage treatment plant, if not used for irrigation, goes to Doggett Creek, a branch of the Canadian River. Raton receives approximately 15 inches of rainfall yearly.

In 1950, the City of Raton entered into an agreement with a cattle company, whereby the cattle company gave the City a site to construct a sewage disposal plant in exchange for the right to use the effluent from the plant for irrigation for a period of 10 years and, thereafter, for $250 per year.

The City is satisfied with the present system of land disposal of its effluent. It is considering additional treatment and may at that time install a system to irrigate recreational areas.

42. Roswell, New Mexico
(1930's - 2.3 mgd)

Roswell is a city of about 40,000 located in southeastern New Mexico. The average rainfall here is seven inches. Any crops grown at or near Roswell must be irrigated.

The City constructed a sewage outfall line (24 inches) in the early 1930's to a point approximately five miles outside the urban area where they constructed an Imhoff tank. The municipal treatment plant was constructed later, three miles closer to the City, and the old line to the Imhoff tank is now used to carry the effluent from the plant. At about eight locations along this line, farmers are able to take the effluent through meters to use for irrigation.

The water shortage is severe here and there is usually a dispute over the rights of each farmer to the effluent. Land with water available for irrigation is worth about $1,000 per acre; without water for irrigation the land is of little or no value ($20 maximum).

In 1964, the City constructed a pump station and a 6-inch force main two miles in length to the Roswell Country Club. The country club uses an underground sprinkling system to irrigate its greens and fairways. Both the country club and the farmers have storage ponds usually from 0.75 to 2 acres in size, and, all together, can store 15 mgd, more or less.

The Air Force abandoned a base here and the City operates the sewage treatment plant at the old base. The average flow to that facility is 0.5 mgd and the effluent is used by a farmer for irrigation. The City plans to construct a pumping station and force main to pump the sewage from the old air base to the other treatment facility. At that time, the air base facility will be abandoned.

43. Santa Fe, New Mexico (1937 - 2.5 mgd)

The rainfall in Santa Fe averages between 13 and 14 inches annually. Water is obtained from reservoirs and wells at great distances and expense. Santa Fe is using and plans to expand the use of irrigation with sewage plant effluent. A report has been prepared which recommends further irrigation or recreational sites. Sewage effluent has also been sold to industrial users. An example is the sale to highway contractors for use in subgrades, fills and embankments. The City has two sewage treatment plants. Some of the effluent from one plant is used to irrigate farm land and some of the effluent from the other is used to irrigate the golf course.

The City of Santa Fe has used sewage effluent for many years for irrigation of the golf course and for some farming use. Approximately 20 percent of the present effluent is used for sprinkling and irrigation. The remainder is discharged into the Santa Fe River which infiltrates into local aquifier or flows to the Rio Grande River.

The City now has 30 existing or proposed parks with a total of 233 acres. With a flow of 2.2 mgd, 1,012 acre feet of treated sewage water during a five-month period will be available from the Siler Road Plant. On an irrigation basis of two and one-half acre feet of water per acre per year, 405 acres of ground could be irrigated. A study has been made covering the installation of a sewage effluent distribution system to serve the major parks. Fourteen parks with a total of 168 acres could be served. This study has envisioned the use of 420 acre feet of water per year. Once the system has been installed, the major cost would be for electrical power. During the last year, purchased water used for the 81 acres of developed parks was $15,373, or $190 per acre. Water rates for 1971 were increased by 10 percent. Cost to irrigate 168 acres at $210 per acre would be $35,280 per year. Estimated pumping costs for using sewage effluent for some parks are $2,120. However, the City is considering acquisition of the system from the private owners, which might reduce the current costs.

The State Health and Social Service Department is requiring sand filtration and chlorination on sewage effluent whether used for sprinkling or discharge into the Santa Fe River and phosphate removal for the latter, but not nitrate removal.

The irrigation system would consist of a surge or equalizing pond at the Siler Road plant, booster pumps operated either by pressure control or time clocks, and a distribution system to the various parks.

45. Clark County Sanitary District, Las Vegas, Nevada (1961

The County operates an overloaded plant about two miles south of the Las Vegas treatment plant. There is a small holding pond at the site. There is a tie-in line to the city plant for overload flows.

Clark County sells water to two power plants and two golf courses. In each case, water is pumped to the power plant and then on to the golf course - one private and one acquired by the County.

The County owns the distribution facility and is paying for it as a credit on the cost of water sold - the entire construction cost was paid by users. Users pay, in addition to 3 cents/1,000 gallons, the cost of maintenance and pumping. A credit of 1.5 cents/1,000 gallons is given towards the cost of construction.

The golf courses pump into and out of holding lagoons in order to facilitate use.

Groundwater has 7,000 ppm solids; thus effluent is considered to be of high quality. June 1972 sales of flow were as follows:

46. Ely, Nevada (1908 - 1.5 mgd)

The treatment plant is located on a portion of a 2,064-acre parcel of land owned by the City's Municipal Water Department, acquired for the water rights appurtenant to the land. It is on a gentle slope draining toward the Murray River.

The effluent weir of the plant clarifier spills directly into the first pond and effluent from the final ponds spills directly into the irrigation distribution ditch which is unlined. The adjacent area has no water available.

47. Incline Village, Nevada (1971 - 0.45 mgd)

Incline Village has a new plant with a very low load in comparison to its capacity; however, as this is a resort community there may be a temporary population increase in both winter and summer to something like three to four times the normal 4,000 persons.

The plant produces an excellent effluent which is discharged through a long force main across the mountain to the Carson River, about 18 or 20 miles distant. A little over half the distance to the discharge point the effluent line passes through the property of a ranch at the upper end of Jack's Valley which opens into Carson Valley.

The ranch has two diversion points from the discharge line and at present only takes effluent from the uppermost point. This passes down an unlined ditch to a portion of the 200-acre site. There is at present only enough flow to irrigate a part of the land and information is not available on application rates. In anticipation of an increase in flow, the ranch has installed a second distribution system.

A small portion of the effluent is diverted upstream but adjacent to the ranch to property under ownership of the Bureau of Land Management for cattle watering.

Clark County Sanitary District

Location	Maximum Per Day	Total Month of June	Jan. 1 - June 30 1972
	(Million gallons)		
Paradise Valley C.C.	1.607	48.212	129.978
Winterwood C.C.	0.950	28.5	72.59
Power Companies:			
Clark	1.6	49.9	387.7
Sunrise	0.139	4.180	12.7
Used by District	0.7	21.0	127.4
Total Sold or Used	4.996	151.792	730.368

The consideration for the effluent entailed an exchange for discharge line right-of-way across the respective properties.

This operation is an excellent example of use of a high quality effluent in a rather arid but apparently fertile area.

48. Las Vegas, Nevada (1959 - 6 mgd)

The City of Las Vegas entered into an agreement with the LDS Church at the time the present water reclamation plant was constructed (1950) to give the church up to 3.5 mgd to irrigate a 620-acre farm. The farm raises alfalfa and sorghum - sudan grass; 2,433 acre feet were used February 15-November 15.

In 1960, the City opened an 80-acre farm run by prison labor. This farm uses up to 1.25 mgd for which it is charged $1/acre foot; 1.25 mgd is sold to an adjacent 80-acre farm, again used to grow alfalfa. This farm has been irrigated since 1962. One mgd is also sold to a power plant for cooling water, at a cost of 2 cents/1,000 gallons, minimum of 1 mgd.

The operation is seasonal and the amount of flow is determined by the user. The disposal facilities are owned by the individual water users.

The balance of the flow goes into a wash which picks up the flow from a county facility and eventually flows to Lake Mead. USEPA has ordered improvement of the quality of the wastewater flow to Lake Mead. Several plans are being evaluated locally. A large power plant is planned 25 miles north of town and all flow may go for cooling with discharge to a dry lake. Other considerations include cleaning up flow in order to get credit for diversion from Colorado River water, or to expand local beneficial use. Present general abundance of domestic water supply appears to preclude local interest in much reuse.

The LDS farm irrigates about 30 acres for 12 hours - rotating to water each plot every 3 weeks. Cattle are pastured on the land and all manure is returned to the land.

Groundwater has 7,000 ppm dissolved solids. Ground is alkaline.

Local officials do not contemplate additional farming applications but greenbelt or golf courses are a possibility.

Figure 18, Las Vegas, Nevada, contains photographs of the pumping facilities and farmed areas.

49. Duncan, Oklahoma (1964 - 0.5 mgd)

Duncan is a city of 20,000 located in south central Oklahoma. The annual rainfall is 33 inches. The predominant industry is agricultural, cattle.

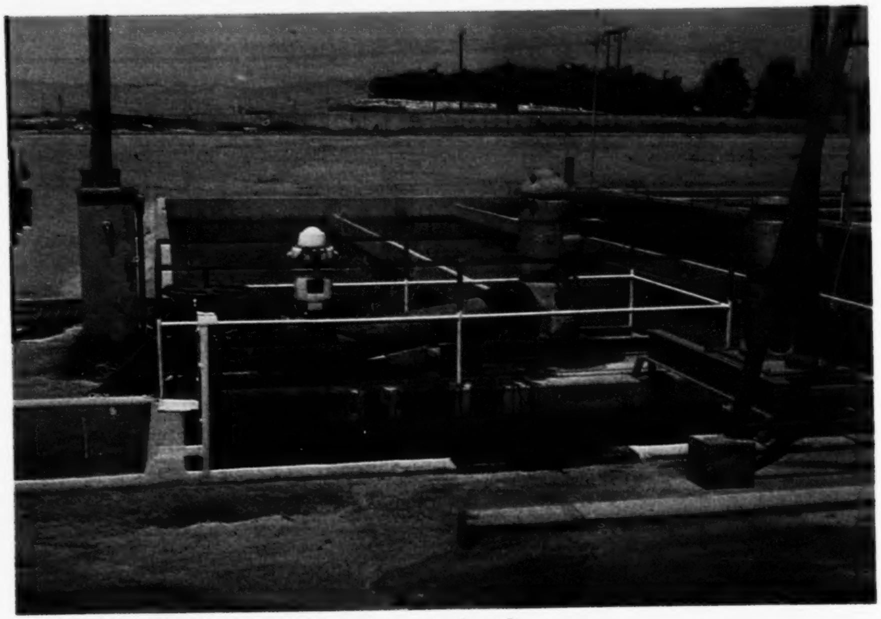
Duncan has two treatment facilities. One is a series of lagoons with a capacity of 0.65 mgd and an average flow of 0.5 mgd. The facility handles the flow from a meat packing plant which is the major industrial wastes contributor. The other plant has a capacity of 4.5 mgd and an average flow of 2.5 mgd. A small portion of the flow from these plants is used to irrigate pasture land nearby. Most of the effluent flows into Cow Creek and eventually into the Red River. In both agreements with the farmers, the City acquired the land for use as treatment sites in consideration for money and the right to use the effluent and the sludge from the facilities.

The farmers operate the irrigation system totally, with no maintenance or capital improvements provided by the City. One farmer pumps the effluent from a lagoon on the City's property, the other has dammed the creek into which the effluent flows and stores the water for irrigation on his own land. Both use spray irrigation. The crops are usually irrigated only two to three times during the summer.

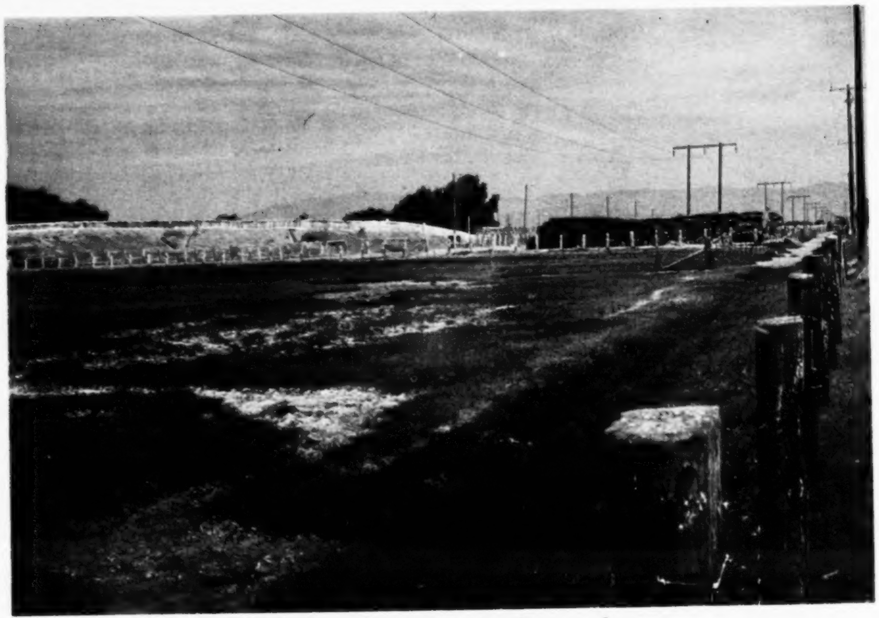
51. Hillsboro, Oregon (1939 - 2 mgd)

The City is served by two city-owned and -operated plants. The plant visited serves the portion of the City that is topographically a tributary to the Tualatin River. This drainage system is in part a combined and sanitary system but no estimate has been made of the proportion. Modern portions of the system are separate.

Cannery wastes arrive at the plant from an industrial outfall from a Birds Eye canning and freezing plant. Flow passes over a shaker screen before mixing with the treatment plant's domestic influent. Treatment plant effluent may be discharged to the Tualatin River or flow to a holding or surge pond from



a. Pump facility from chlorine contact chamber



b. Irrigated city prison farm. Baled hay in background

FIGURE 18
LAS VEGAS, NEVADA

which sprinkler pressure pumps take suction. The State of Oregon requires at least a five-to-one dilution ratio for the river to be used as a point of discharge. This ratio is not reliable during the summer months, thus land disposal is necessary.

A buried pipe sprinkler system irrigates a healthy stand of grass on the gently sloping bank of the river. The slope is not over 2 percent, although the site is slightly rolling and has the appearance of a park. The grass is regularly cut but is not harvested. It is merely left in place on the ground.

52. Milton-Freewater, Oregon (1946 - 2.7 mgd)

Milton-Freewater has a secondary plant which treats a flow which is primarily domestic. The effluent from this plant discharges into a gravity outfall which serves various canneries by its upstream branches. This outfall discharges into a series of ponds, totalling 18 acres, adjacent to the farm which uses pond effluent for. irrigation. The pond site is about four miles from the treatment plant.

The farm takes the effluent on a basis of no payment either to or from the City. The City is, however, obligated to do some annual maintenance of the ponds which amounts to about $2,300 per year.

Crops that have been irrigated are alfalfa and wheat, but the proportions of each may vary at the farmer's discretion. As the farming is conducted on an area exceeding 1,000 acres, supplemental water is used from wells and from a stream. No clear data are kept regarding proportions of source water utilized on particular portions of the farm.

53. Pennsylvania State University State College, University Park, Pennsylvania (1963 - 0.5 mgd)

During the course of the in-depth examination of this project, the following persons were interviewed:

Dr. Earl Myers
Agricultural Engineering

Dr. Jack Nesbitt
Sanitary Engineering

Dr. Louis Kardos
Soil Physics

Prof. Richard Parizek
Groundwater Hydrologist

Dr. William Sopper
Forest Hydrology
(Phone conference only)

Gilbert Aberg
Director of Science Information

John Kello
Facilities Engineering
(In absence of Mr. Kneen)

David Long
Civil Engineering
(Brief discussion)

In 1962, the University was faced with a decision on correcting eutrophication problems in the stream which received the effluent from its sewage treatment plant. The State Health Department raised questions about phosphorous and nitrogen removals and improvements in effluent quality in general. The sewage treatment plant was increased in capacity to 4 mgd, to treat all of the University flow and the sanitary sewage from a portion of the borough system. The other parts of the borough are served by another authority plant which is not involved in effluent irrigation at this time.

The University set up a "committee" of its various science departments to advise on the best means of meeting state requirements and solving the pollution problem This group of engineers, limnologists, geologists, agronomists, silviculture scientists, hydrologists and others proposed a research project to determine the effectiveness and economy of utilizing treatment plant effluent for irrigation disposal on university-owned lands in the area. Out of these proposals and studies has come the so-called "Pennsylvania State Waste Water Renovation and Conservation Research Project."

Alternatives available at the time were: Plant modifications to provide higher degrees of treatment and removal of P and N;

injection of the effluent into deep wells; or construction of a 10-mile outfall to Bald Eagle Creek at an estimated cost of $10 million. The university group proposed irrigation as a better means of effluent disposal and the capturing of the nutrient values of the wastewater for crop and forest enrichment. Pretreatment would provide secondary treatment by two-stage trickling filters, followed by activated sludge or by a modified two-stage activated sludge treatment in Halmur-type oxidators.

This decision to initiate the recommended demonstration project, covering a set amount of the total effluent flow of 3.7 mgd, approximately 0.5 mgd to be irrigated, was based on availability of university lands in a farming area; adequate soils for irrigation consisting of sandy-loam and clay-loam; depth of goundwater ranging from 100 feet to some 350 feet; the availability of university personnel to control and evaluate data; opportunity to utilize crops of hay and corn for animal feeding at the University farm; and means for evaluating forest tree growth, with and without irrigation.

Thus, the decision-making phase of the project was clarified. Proof of the effectiveness of the project is found in the present plans to enlarge the entire program to handle approximately 4 mgd of effluent, the total effluent of the treatment plant. It is important to record that the decision to go full-scale was reached after about six years of research - four years ago - but that the project was held up pending the obtaining of adequate land from the Commonwealth, in exchange for other lands owned by the University. The project, now under consummation-planning and early construction, will cost over $2.25 million. No better proof of the success of the 0.5 mgd-pilot work can be found than the decision to proceed with a full-scale project involving some 516 acres of irrigation area.

Spray irrigation has been successful in disposing of the effluent, increasing reed canary grass hay yields, increasing corn yields, increasing wood growth in mixed hardwoods, and other tree stands. The groundwater quality has not been adversely affected; effects on wildlife, bird and insect life are now being quantitatively evaluated.

Design Factors for Irrigation

In all, approximately 80 acres of land, both crop and forest areas, have been spray irrigated. Plots have been varied as part of the demonstration project, so it is reported that about 70 acres are in use-rotation at any one time. It was reported that the split between the crop and forest areas has been varied; now, it is about 50 percent to each such area.

The details of pretreatment have been given. Heavy metals are low because the community sewage flow is basically residential with no industry and only a limited commercial area. University laboratories do contribute chemicals to the flow. Design was on the basis of sanitary sewage effluent only.

Sewage effluent is delivered at a uniform rate of 0.5 mgd from a distribution chamber at the treatment plant outfall into the receiving stream. Excess flows diverted from the outfall, over and above the 0.5 mgd rate, are bypassed to the stream. Effluent is pumped at 226 psi and delivered to the farthest distributor header at approximately 50 psi, with higher pressures prevailing at areas closer to the effluent pumping station.

The force main is 6-inch asbestos-cement pipe. At the irrigation areas, stationary aluminum piping and vertical risers are used. Spray head risers are of uniform height in reed canary grass hay areas and corn areas; in the forest areas, prior to 1968, some spray heads were 42 feet high above the red pine canopy. All are now set at lower levels, 3 to 5 feet.

Soil conditions are variable. In the

Gameland Areas, the soil is deeper and sandy loam, with 20 to 160 feet of residual overlay above recurring beds of sandstone, quartzite and dolomite. In the Agronomy-Forestry Area, soil overlay ranges from 5 to 80 feet in depth, with a dolomite bedrock. The soil is somewhat less permeable, of more clay-loam character. The forest mulch cover was not disturbed and undercover weeds and grass are not cut in the nonfarm areas. The mulch improves the ability of the area to absorb winter spraying.

The areas used for spray irrigation are surrounded by some measure of buffer zone but the areas for buffering vary. No attempt has been made, apparently, to adhere to any minimum buffer area. Opinions were expressed that aerosol pollution hazards are minimal or absent. In one area - the Gameland Area - a store and some residences are less than 300 feet from a spray area. A new community, known as "Toftree," is situated along the Gameland property line and in general proximity to the spray areas that will be used in the 100 percent irrigation project.

In the Agronomy-Forestry Area, buffering areas are greater, but not by deliberate design. The plot plan shows the striking situation where the university water supply wells are located within 1,000 to 5,000 feet from the spray areas - and in the direction of the downstream flow of groundwater. The researchers are certain that no hazard is involved. As stated, groundwater tables are deep - from 100 to 300 feet below the spray areas which are in upland areas.

Much of the spray irrigation demonstration has been based on an application rate of 2 inches per week, with actual application for a continuous period of 12 hours and a resting period of 6-1/2 days. This rate was felt to be well below the infiltration capacity of the soil. Experimental application at the rate of 1 inch per week was tried, as were rates up to 6 inches per week. The new full-scale project will be based on 2 inches per week, apparently, but some changes may be provided. The per hour rate has been varied from 1/6 inch to 1/4 inch - the latter rate being utilized for an eight-hour dosage period. The 12-hour application period has been favored because of simplicity of operation. The same rates have been applied to open crop fields and forest areas.

No holding facilities were provided at the irrigation site or the sewage treatment plant because application for 12 months per year was anticipated. In the Gameland Area, for crop lands and forest lands, irrigation is carried out throughout the winter. In the Agronomy-Forestry Area, irrigation is from mid-April to mid-November on the corn rotation and forestry areas and year-round on the reed canary grass area.

New project plans call for a holding basin for effluent at the treatment plant to provide flow equalization at a uniform irrigation rate, 12 months per year.

Sprinkler spacing varies by design from 40 x 60 feet to 80 x 100 feet.

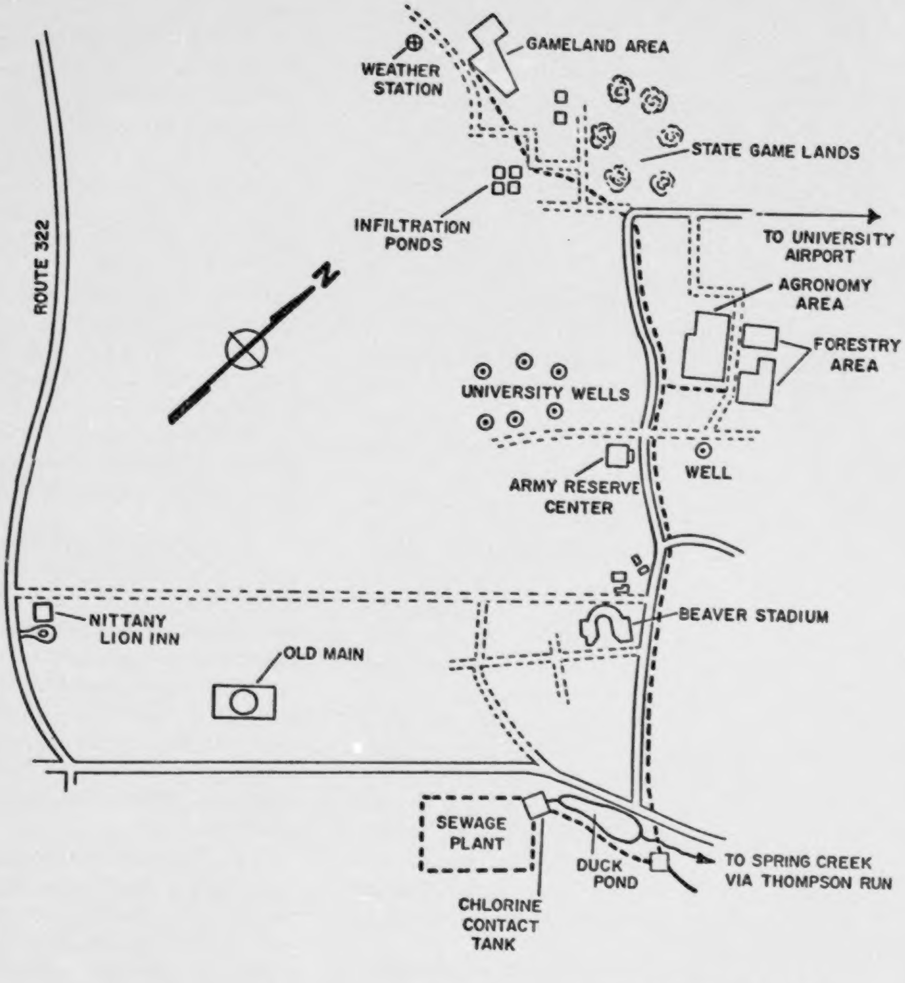
Monitoring provisions were made in the design of the 0.5 mgd study project; they will also be made for the 4 mgd 100 percent project. For example, in the Gameland Area six monitoring wells were installed to groundwater level - 150 feet to 300 feet deep, approximately. Lysimeter stations were installed in clusters, to varying depths, to determine the character of the capillary water contained in the soil. Samples are taken by suction device. Pan lysimeters were also installed to capture free water in the soil and determine its quality. Monitoring in the new project will be expanded.

Beginning in 1969, a supplementary study has been carried out on the irrigation of coal strip mine spoil with effluent and sludge. The ability to convert barren strip mine areas to productive land for crops and trees has been demonstrated.

Limited tests have been carried out with sludge-injected effluent spray irrigation in the forest and crop areas of the project. The two-stage anaerobically digested sludge is injected into the system at a rate of 25 gpm. The sludge injection is not started until the wastewater flow has been on two hours and is stopped two hours prior to shutdown. Use of the practice in the expanded system will depend on the outcome of the research.

Operation and Maintenance Procedures

- The number of operation personnel was not determinable. Only one person was noted on the site during the inspection. Valve changes and spray area shifting are manually accomplished according to a preset plan.
- The land cover was not changed when the site was designed and developed. The forest cover is not cleared. Three hay crops are harvested yearly. One corn crop is harvested. All yields are used in feeding university animals in the Farm Department operations. Income from the crops is accrued to the Farm Department Operations.
- The University has no limitations on the feeding of irrigated hay or silage crops to animals. No reference was made to state regulations in this respect.
- Comparative yields for irrigated and nonirrigated areas have been carefully studied. More than that, such comparative studies have been augmented by yields in areas irrigated with *water* and compared with *effluent* yields. This applies to crop areas. Literature gives the findings. Suffice to say here, yields have been doubled and tree growth doubled, in general.
- Irrigation spray head orifices have clogged, at times, but they are readily cleared. Head orifices have been increased to avoid clogging; in some cases, sprinklers with two orifices were converted to a single, larger bore opening. Winter operation sprays in the 12-month areas has experienced no serious freezing because the lines and sprays function continuously for the 12-hour periods and are then shut down and drained when a new area is placed in service.
- From 1962 to 1967, a precipitation deficit of some 42.65 inches was experienced, according to one interviewee, and irrigation was especially dramatic in effect.
- Analyses of soil indicate the ability to remove P. Removal of N is by crop uptake and by denitrification; any N passing through the upper four feet of soil will probably appear in the groundwater. Groundwater analyses have disclosed no detrimental effect on quality. Virus infection is considered remote.
- Soil clogging has not been a serious problem. Some ponding is noted in some of the small depressions in the rolling contour of the irrigated areas, but they drain during the six and one-half day resting period.
- No efforts have been made to prohibit trespassers. The area is somewhat remote. A gate was originally used at the entry to the Agronomy-Forestry area, but prowlers tore it down and the University did not feel it necessary to replace it. Posted signs were not observed. The general feeling is that the area is safe and that any hazard of infection would be zero or minimal.
- No runoff of surface water from the site was reported; none was noted despite the fact that the site was inspected during a heavy rain period.
- Monitoring of soil and groundwater has been described. Deep well monitoring was more frequently maintained in the earlier years than at the present, apparently on the basis that enough data have been accumulated to show the absence of any effects. Dr. Kardos reported that he preferred continuation of groundwater monitoring by suction lysimeters. Energetic monitoring programs will be involved in the new full-scale project.
- Inquiries on costs of construction and operation brought the response that such data would be indeterminate because the research nature of the studies involved nonroutine costs of varying nature and frequencies.


GAMELAND AREA
WEATHER STATION
STATE GAME LANDS
INFILTRATION PONDS
TO UNIVERSITY AIRPORT
AGRONOMY AREA
FORESTRY AREA
ROUTE 322
N
UNIVERSITY WELLS
WELL
ARMY RESERVE CENTER
BEAVER STADIUM
NITTANY LION INN
OLD MAIN
SEWAGE PLANT
DUCK POND
TO SPRING CREEK VIA THOMPSON RUN
CHLORINE CONTACT TANK

Courtesy Penn. State University

B-60

Wastewater Renovation and Conservation Research Project

FIGURE 19
THE PENNSYLVANIA STATE UNIVERSITY

Pressed for cost information on the 0.5 mgd project, officials indicated that some $500,000 has been invested in the project in the past 10 years. The new project's cost will be somewhat over $2,250,000, without land costs, engineering, and other extraneous items.

54. Dumas, Texas (1962 - 1 mgd)

Dumas is a city of approximately 10,000 population located in the center of the Texas panhandle. The annual rainfall in Dumas is 19.5 inches.

The effluent from the city disposal plant is emptied into a lake which varies in size. At the time of inspection the surface area was approximately 5 acres. There is no surface runoff into the lake and it consists of effluent only. Some of the effluent is lost by percolation and some by evaporation, the rest is used for irrigation by the farmer owning the adjoining land.

The farmer always uses all of the water in the lake; it has never overflowed since it was constructed about 10 years ago. He irrigates both wheat and maize crops. Some of the wheat crop is harvested or may be used for grazing cattle, depending on wheat prices, government farm regulation, and other farming factors. Generally, maize is planted in June, irrigated four times, and harvested in October. Wheat is planted in September, irrigated twice, more or less, and harvested in July. The farming operation is very well carried out. The effluent lake and irrigation process cause no odor or apparent problem. The irrigated land is adjacent to the city limits and across the street from urban property. The value of the irrigated land is higher than the adjacent farm land due to its proximity to the City and possible redevelopment to a higher use.

The City of Dumas incinerates its solid wastes and a small amount, about 3,000 gpd of the effluent, is used in the process to wash the ash out of the smoke to prevent air pollution. The incinerator is adjacent to the effluent lake.

55. Kingsville, Texas (1952 - 3 mgd)

Kingsville is a city in southern Texas near the Gulf of Mexico. It has a population of 30,000 and is surrounded by the King Ranch. The average annual rainfall is 30 inches. Kingsville has no treatment facilities other than three lagoons totaling 17 acres. One lagoon is on one ranch and the other two are located on a separate property. The owner of the latter property allows the City to maintain the lagoons on his property in exchange for the use of the effluent for irrigation. The raw sewage is conveyed to the lagoons by force mains. Both raw sewage from the force main and water from the lagoons are used as needed depending on the weather. In dry years, all of the effluent may be used and in wet years the lagoons overflow into an adjacent stream

Kingsville is planning to construct two treatment plants in the near future with a capacity of 4 mgd. The City is working to acquire 15 acres of land for the facilities in trade for the use of the effluent for a number of years. The landowner plans to change from farming to ranching at the time the new plant is constructed. The ranch with one pond is not making any use of the water from the lagoon on its property.

56. La Mesa, Texas (1960 - 0.6 mgd)

La Mesa, Texas, is a city of 11,400 located in west central Texas in an area where cotton is the principal crop. The average rainfall there is 16.7 inches.

The effluent from the treatment plant is stored at the plant site in 18 acres of lagoons. From these lagoons it is pumped to one public golf course and the two city parks. A gravity line carries some effluent to the La Mesa Country Club. The irrigation of the parks is done by the Park Department.

The public golf course is leased to a nonprofit corporation that handles irrigation of that golf course. The country club is private and maintains its own system All of the effluent is used for irrigation; that usually is plenty for all needs. If more effluent is available than required for irrigation, it is used for irrigation rather than let it enter the dry watercourse. There is a small reservoir at both the country club and the public golf courses but none at the parks.

Movable above-ground pipe and spray systems are used. The pump line that serves the parks and public golf course is approximately 2 miles long and varies in size from 8 to 4 inches. It was constructed of salvage water pipe, some of it in place, and has booster pumps alongside of it. The gravity line to the country club is about 4,000 feet in length and was paid for by the country club.

Effluent is used to wet down the rodeo grounds during rodeos and also to irrigate a small field of hay for the horses in the sheriff's posse.

57. Midland, Texas (1950 - 4.3 mgd)

The City of Midland is located in western Texas midway between Fort Worth and El Paso. The population of Midland is 62,000 and the annual rainfall is 15 inches.

The City of Midland has purchased 1,200 acres of land beginning in the 1920's, southeast of the City. The land is used for park, disposal plant, landfill, and leased for farming. There are storage ponds on the site capable of storing approximately 150 mg of sewage effluent.

The City leases the farm land, approximately 700 acres to a farmer. The lease term has been five years with a cancellation clause if the City needs the effluent for another public purpose. The lease does not have any public health restrictions but the City may generally control the farmer's use of the effluent. The City pays, under the lease, 25 percent of the cost of fertilizer, if used, receives one-third the income from the milo crop and one-fourth the income from the alfalfa and cotton crops. All of the operation costs of irrigation and farming are paid by the farmer.

The City also plans to construct pumping facilities to supply effluent to industrial users. Generally, more effluent is available in Midland than is needed by the City for irrigation. All effluent is utilized - either lost by percolation and evaporation or used for irrigation.

58. Monohans, Texas (1945 - 0.8 mgd)

Monohans is a city of approximately 8,000, located in west central Texas. Oil production is the primary activity in this area. The soil here is sandy and will accept an almost unlimited amount of water. The annual rainfall is 12 inches.

The effluent from the sewage treatment plant is sold to a rancher for a token amount. The ranch irrigates 38 acres of pasture land using two small reservoirs, ditches, and flooding. The ranch irrigates 12 hours a day and 7 days a week. The soil readily accepts this amount of water. About 50 head of cattle and horses are grazed. The effluent is their source of drinking water. Unirrigated land surrounding the property will support only mesquite and desert plants.

59. San Angelo, Texas (1933 - 5 mgd)

San Angelo is a city of 65,000 located in west central Texas. The principal industry is a suture manufacturing facility owned by Johnson and Johnson. The average annual rainfall is 18.5 inches.

The City of San Angelo owns approximately 750 acres of land several miles from the city limits. At this location, it has its sewage treatment facility and uses the balance of the land for storage of the effluent and farming. Treatment consists of primary settling only. Some of the effluent is stored in a system of lagoons for about a week before being used for irrigation. Some of the effluent is used directly from the plant without storage in the lagoons. Effluent not stored but used directly from the plant is generally used on pasture land. Attempts to use it on feed crops result in burning the plants.

The City raises, bales, and sells hay on the farm, and grazes an average of 500 cattle on the pasture land. The pasture grasses are coastal bermuda and fescue. The stock is not owned by the City. Four city employees operate the farm and it is financially successful. The farm has been terraced into 1- to 2-acre plots, called borders, which are level with a dike on all four sides, approximately 18 inches in height. Water is brought to the borders through an underground pipe system utilizing gravity flow from the lagoons. One foot of water is usually put in each border every two weeks. Sludge is stored in a separate lagoon and is put on the pasture in liquid form.

60. Uvalde, Texas (1938 - 0.9 mgd)

Uvalde is a city of 9,000, located in southern Texas. It is a center for deer and bird hunting. The average rainfall in Uvalde is 24 inches.

In 1937, the City of Uvalde acquired approximately 100 acres of farm land from the county by donation. The site had previously been the county pest farm. This site is leased to a farmer who raises grazing crops for cattle. The City irrigates his crops by the border flood method. The City has more effluent than is required for the crops and some runs off to the stream. The operation is not profitable to the City and is only used because it has the land. The City plans to continue this method of disposal; however, it does not intend to expand its land ownership and the surrounding landowners do not want to use the effluent. So as the quantity of effluent increases, more will be discharged to the receiving stream.

The operation is unusual in that the city personnel do the irrigating of the farmer's crops. The area is composed of both steep land which is irrigated by sprinkling, and flat land which is irrigated by border flood. Rates of application vary with the amount of effluent available.

61. Ephrata, Washington (1972 - 0.44 mgd)

Ephrata provides primary treatment, followed by oxidation ponds, for almost exclusively domestic sewage. Prior to 1972, disposal was completely by means of evaporation and percolation from the ponds. The soil is evidently very porous, of volcanic origin, and the groundwater table is about 70 feet below the pond bottom. Nevertheless, the Washington State Environmental Protection Agency directed the City to change its disposal method and the City chose to install a spray irrigation system.

A permanent system of buried irrigation headers was installed in rows across the field. Some difficulty was experienced in trench excavation because of the large (up to 3 feet) lava rock fragments encountered. The headers feed vertical risers with sprinkler heads and they are valved for manual operation. There was no evidence of flooding problems as the soil absorbs moisture readily. It is covered with natural brush and weeds. At present, there is no intention of seeding to foster a forage crop; although the land is virtually impossible to till because of the rock, it might be possible to start a grass suitable for the pasturing of sheep. As 1972 was the first partial season of irrigation, there were no data on the effect of spraying on either the growth or soil.

As a matter of changing the method of disposal to 100 percent spray irrigation, the ponds were sealed with a clay that had to be imported. From now on, the sprinklers will be used exclusively during nonfreezing weather. The ponds are designed to have enough storage capacity to contain winter freezing temperature flows.

62. Quincy, Washington
(1955 - 0.75 mgd)

Quincy's treatment plant includes primary treatment with oxidation ponds and separate sludge digestion. It is located in an exclusively farming area on a site including an irrigated area of only 33 acres.

The farming activity is conducted by a tenant farmer who has the obligation of applying effluent from the oxidation ponds as necessary to leave pond capacity available for plant inflows. Because the farming area is too small to utilize the quantity of water available, the operation is precarious. A crop of sprouting winter wheat was observed, which of necessity must be flooded soon and which would result almost certainly in the loss of the planting. Negotiations are under way for the purchase of additional land to cope with this problem

Quincy, in addition to domestic sewage treatment and disposal, treats and disposes of potato processing waste from a Lamb-Weston packing and freezing plant. The treatment and disposal by the City is completely separate from the domestic waste system and is conducted at a different location.

Wastes from the plant are piped by the company about 1,000 feet to a small city plant which includes a clarifier and sludge-type vacuum filter. The potato wastes settleables are dewatered on the vacuum filter and sold by the City for cattle feed. This produced a $4,000 revenue to the City last year. An outfall extends from the clarifier to a series of oxidation ponds located some two miles away. These ponds cover an area of 60 acres. The first pond is equipped with five 150-HP aerators. The overflow from the final pond discharges into a ditch which, in turn, empties into a Bureau of Reclamation drain. Water in this latter drain mingles with other discharges (irrigation return flows, etc.) and flows into a reservoir from which it is reused.

The potato wastes influent contains about 2,500 mg/l BOD, 4,000 mg/l suspended solids, and the flow average is about 1.5 mgd. The City experienced a serious odor problem at the pond site until the aerators were installed. Pond effluent now contains about 25 to 50 mg/l BOD, 100 to 15 mg/l suspended solids and 75-100 mg/l COD.

63. Walla-Walla, Washington

The City has a modern treatment plant which produces a high quality effluent (about 10 cfs) discharging into a stream adjacent to the plant. This practice has been continued over a long period of years and downstream users apparently have some rights to the water. The City wished to discontinue this discharge and entered into a suit to settle rights. A judgment was made that downstream users rights would continue for some years in the future. The water is used by a considerable number of farmers on Walla-Walla onion crops, pasture, etc., but no information exists on any details of use.

The City was under a directive of the State of Washington Environmental Protection Agency to remove its treated cannery wastes from the stream by this past season so land was purchased, a land application system was designed and installed and is now in use. It is the City's intention to eventually dispose of both cannery and domestic effluent through its irrigation system.

There are two outfalls to the treatment plant site, one solely for cannery wastes and one for domestic flow. The cannery wastes line terminates at a wet well from which it is pumped to an aerator and cominutor. It is then pumped a distance of about two miles to the 1,000-acre disposal area located on higher rolling ground. Seven hundred acres of the land have two banks of permanently installed sprinkler systems which are remotely controlled hydraulically from a control house serving each bank. Control equipment can be programmed to accomplish any desired sprinkler sequence, time, and cycle.

It is proposed to plant the area to alfalfa and watch soil nitrogen content for about three years and, if necessary, to rotate with some other crop such as timothy hay. The system has been carefully thought out including possible agronomy problems. The City is aware of the necessity of maintaining good control and recognizes the need of data-gathering to be able to insure success. This will be an operation of future interest to the art.

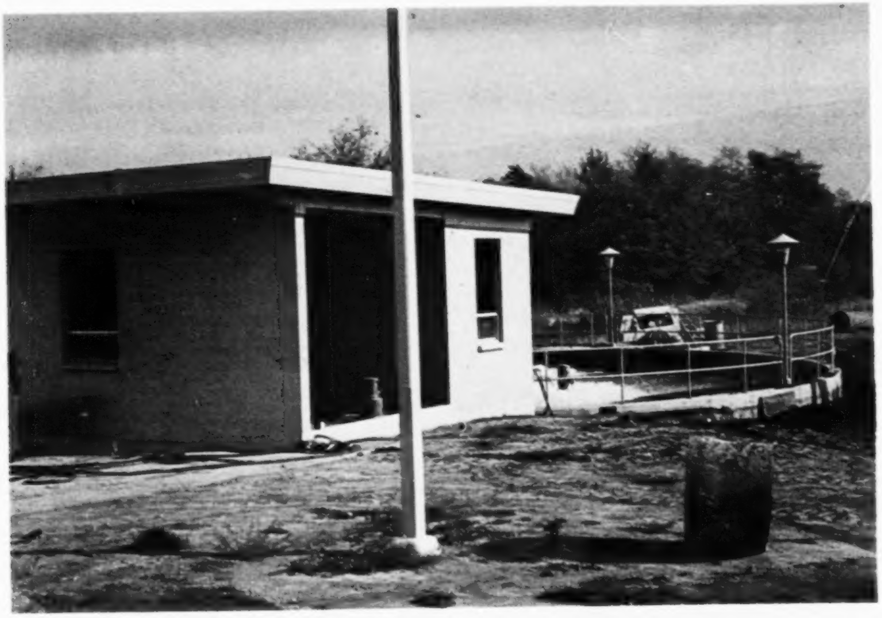
Figure 20, Walla Walla, Washington, contains photographs of the irrigation controls, influent aerator, and the typical valley terrains of the area.

64. Cheyenne, Wyoming (1881 - 7-7.5 mgd)

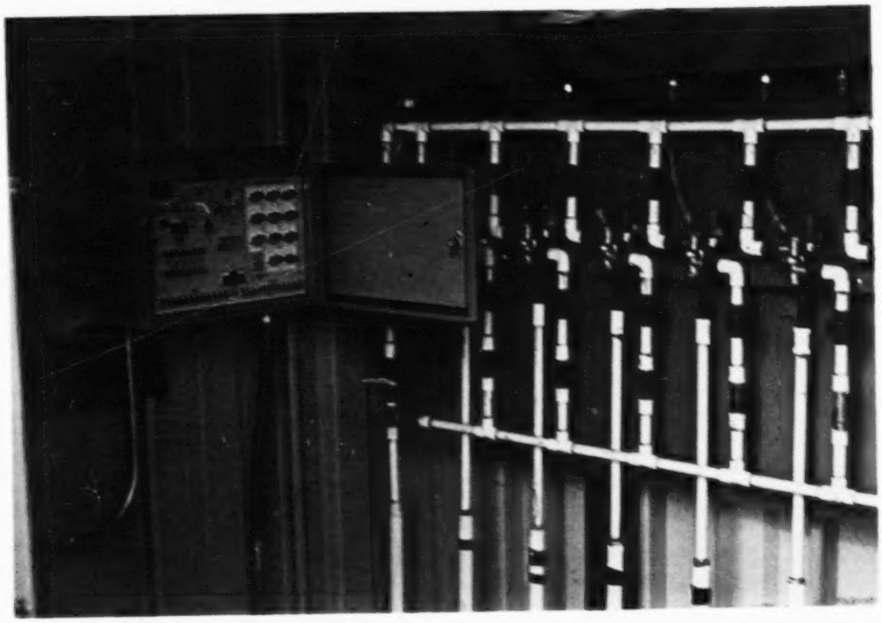
The City of Cheyenne has an overloaded secondary treatment plant and effluent is discharged to a stream. Approximately one mile downstream, a large ranch has created a reservoir. The reservoir originally had approximately 100-acre-feet capacity but now has only 58 acre-feet. There are 1,200 acres of grass and hay, as well as 130 acres of alfalfa, irrigated by flood irrigation. The ranch attempts to water the entire spread three times a year: April 1, June 1, and August 10. Each watering takes approximately five weeks. Cattle graze the area in the winter.

The ranch was started in 1881 and has rights to 17 second feet of flow. Within five miles downstream, the stream goes underground. Ranches along the stream have rights to flow from the stream and utilize it on an as-available basis for irrigating hay. Perhaps 80 acres are irrigated.

The normal ratio of calcium to



a. Pump house and influent aerator



b. Hydraulic sprinkler controls

FIGURE 20
WALLA WALLA, WASHINGTON

phosphorus in hay was reported to be 9 to 1; however, in irrigated hay, because of the use of sewage effluent, the ratio is 1 to 1. The ranch obtains a premium for its hay. No commercial fertilizer is used.

The ranch has the stream flow checked for quality as stock water. It has not found nitrogen high enough in the creek to be concerned for the cattle. In the area of the ranch, it is 200 feet to groundwater. The soils are gravel and sandy loam, characteristic of an of an old river bed.

The ranch runs 2,700 head of cattle and is the third largest Hereford ranch in the United States.

Figure 21, Cheyenne and Rawlins, Wyoming, contains photographs of the facilities.

65. Rawlins, Wyoming (1880

The City of Rawlins, Wyoming, has no wastewater treatment facilities. Outflow from the City enters a series of lagoons east of town where some stabilization occurs. Evaporation is reported to be 11 inches per month in the area and undoubtedly much of the flow is evaporated. It is reported that the lagoons currently need dredging to restore capacity. The system was started before 1900.

From the lagoons the flow enters Sugar Creek and flows approximately 7 miles to a point just north of Sinclair, Wyoming, where flow from an Imhoff tank, which treats the residential units of Sinclair, also enters the creek. The flow goes to a large reservoir on an alfalfa ranch.

At the ranch, 137.5 acres are spray irrigated at a rate of 3/4 inch every 60 hours. Seventy acres are flood-irrigated at a rate of 4-5 inches once a month from May to early September. Alfalfa yields are said to be excellent. This is the only irrigated land in the entire area. Cattle are run on the land when not irrigating, and during the fall, winter, and early spring the reservoir is allowed to fill. However, because of evaporation it is a slow process.

The stormwater from Rawlins is allowed to flow into a separate lagoon from which it is evaporated. The City is under orders from the State Health Department to build a series of oxidation and evaporation ponds.

Under the water laws of Wyoming, the City is under no compulsion to release water to Sugar Creek; however, once it does, the Duncan Ranch has water rights to the flow. Thus, the land use will be terminated if the City proceeds with plans to construct the facilities.

Other Facilities

During the course of the study, two percolation-type facilities were visited. These were Flushing Meadows, Phoenix, Arizona, and Whittier Narrows, Los Angeles, California. The narrative report concerning Flushing Meadows is enclosed in order that information concerning this method of land application might be available.

Background

In the Phoenix area, one-third of the agricultural water comes from groundwater. The remaining two-thirds of the irrigation water and the municipal supplies are obtained from surface reservoirs on the Salt and Verde Rivers. In recent years the groundwater table in the Phoenix area has been dropping 10 feet per year. In 1971, the water table dropped 20 feet. The depth to groundwater varies from 400 feet in the Mesa area to 50 feet near the Salt River in the Phoenix area.

Flushing Meadow, Phoenix, Arizona

In 1967, the Flushing Meadows Project was begun. The objectives were to study the treatment of sewage effluent by rapid infiltration and determine infiltration rates. Specifically, the removal of BOD, suspended solids, nitrogen, fluoride, and pathogenic organisms was important. It was desired to obtain renovated water of a quality sufficiently high to permit unrestricted irrigation.

A site was located west of Phoenix within the floodplain of the Salt River. The 2-acre site was divided into six basins that are 20 feet wide and 700 feet long. The soil is a sandy loam made up of 2-3 percent clay, 50 percent silt, and 47 percent sand. Infiltration rates of 1 foot per day or 350 feet per year are regularly achieved by flooding for 14 days and resting 10-20 days. During the two weeks of inundation (surcharge is about 1 foot), the infiltration rate drops from 2.5 feet per day to 1.5 feet per day with an average of 2 feet per day. During the summer, 10 days are sufficient for drying, re-aeration, and biological oxidation which restore the infiltration capacity, but winter operation requires 20 days. The permeability of the soil using well water is 4 feet per day. The groundwater table is at a depth of 10 feet. Several articles and reports were obtained describing the technical aspects of the project. Removals were: BOD, fecal coliform, and suspended solids - essentially complete; phosphorous and fluoride, 70 percent; nitrogen, 30 percent; and boron, lead, and cadmium - essentially zero.

23rd Avenue Project, Phoenix, Arizona

Dr. Bouwer is applying for a grant from USEPA for a project near the 23rd Avenue sewage treatment plant in Phoenix. This project would involve rapid infiltration of 15 mgd on 40 acres, followed by pumping of the renovated water into a nearby irrigation canal. The wastewater would have secondary treatment by activated sludge at the 23rd Avenue plant. Because the effluent suspended solids concentration is above 50 mg/l, a holding reservoir for sedimentation will be provided prior to infiltration. The existing 40-acre oxidation pond will be drained and divided into four parallel basins with wells along the central median to recover the renovated water. The water table at this location is at a depth of 50 feet.

If this project proves successful, a third-stage project would be built, utilizing secondary effluent from the 91st Avenue wastewater treatment plant. This plant has a capacity of 60 mgd and is presently treating 72 mgd, or 80,000 acre feet per year. The City of Phoenix has an agreement with the Buckeye Irrigation District that the City will allow Buckeye to use 28,000 acre feet of effluent per year. In exchange, Buckeye will not press claims to an equivalent volume of water it claims was lost to the district due to upstream operations by the City.

The secondary effluent flows in a channel westward past the Flushing Meadows Project (where 0.6 mgd is used as influent) and then 20 miles to the Buckeye Irrigation District. The average water use for irrigation in the area is 4.5 acre feet per acre per year.

Rio Salada Project, Phoenix, Arizona

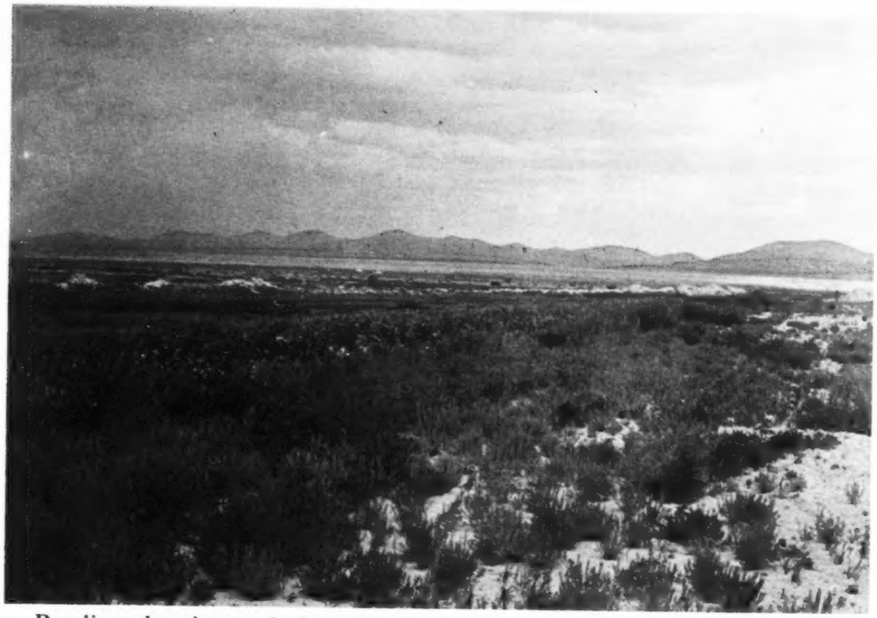
This is another reclamation project proposed for the Mesa-Tempe area. The effluent from Mesa's 5-mgd trickling filter plant flows into the dry Salt River bed and infiltrates within a half-mile of the plant. The project would involve drilling a well to recover the water, building a flood control channel, and establishing a greenbelt area along the Salt River.

Nitrogen Studies

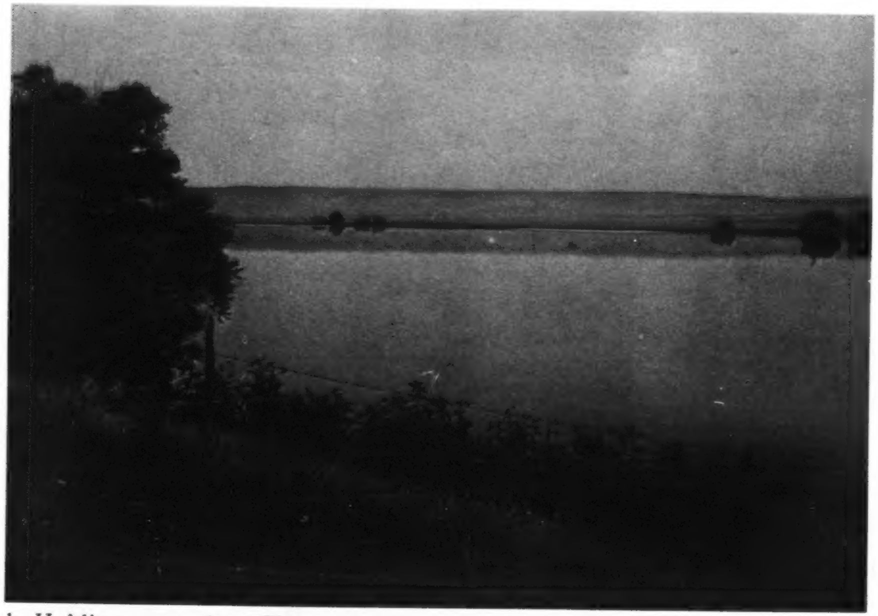
In addition to the field studies conducted by the Water Conservation Laboratory, laboratory studies have been conducted specifically aimed at determining nitrogen removal mechanisms. These studies have been conducted primarily by Dr. J. Clarence Lance.

It has been found that ammonia nitrogen in the sewage effluent is absorbed in the soil within the top three feet during inundation. During rest periods, the bacteria in the soil oxidize ammonia to nitrate which frees the absorption sites. When inundation begins again, anaerobic conditions quickly prevail and some denitrification occurs; however, due to the high rate of infiltration, a slug of nitrate is flushed into the groundwater. Using the laboratory soil columns, Dr. Lance has determined that a 30 percent reduction in total nitrogen occurs. If the slug of high nitrate can be recycled, the overall nitrogen removal would be 80 percent.

After a long period of 14 days on, 10 days off, the ability of the soil to absorb ammonia decreases. At this point a change in cycle to two days on, five days off, stimulates the nitrifiers and rejuvenates the ability of the soil to absorb ammonia. During this cycle, denitrification essentially ceases.

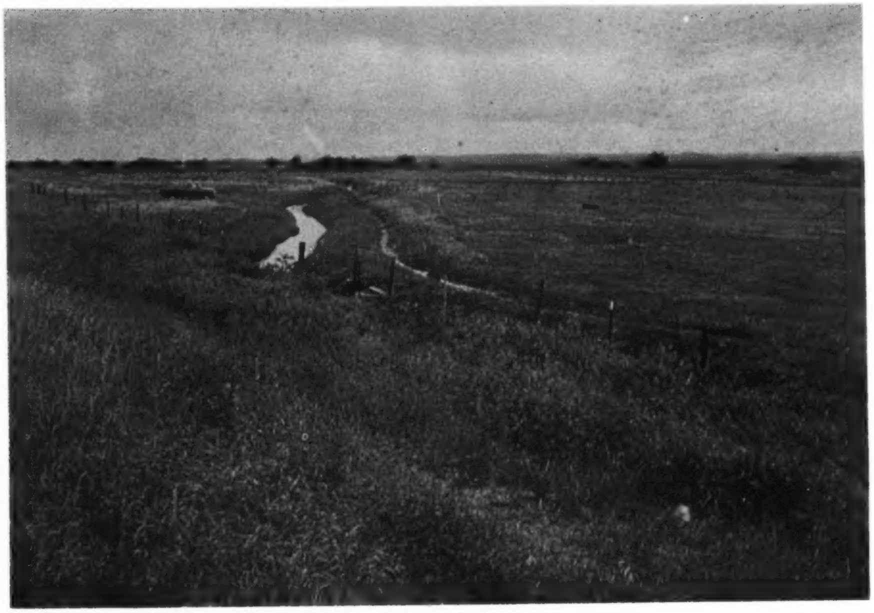


a. Rawlins, showing typical sagebrush condition of nonirrigated areas.
In background spray irrigation of alfalfa

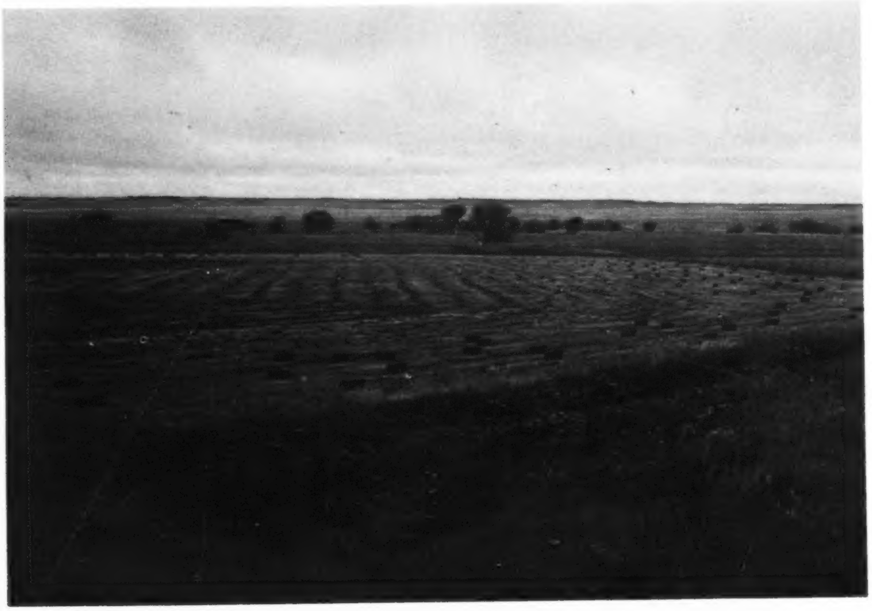


b. Holding reservoir at Cheyenne.
Lake has lost almost one-half of its original capacity.

FIGURE 21
CHEYENNE AND RAWLINS, WYOMING



c. Cheyenne, distribution ditch to hayfield



d. Cut hay, Cheyenne

FIGURE 21
CHEYENNE, WYOMING

INDUSTRIAL OPERATIONS

1i. Green Giant Company (- 1 mgd)
Buhl, Idaho

The Buhl corn processing plant discharges wastes which include cleanup water, floor drops of corn, and can spillage and wash water. This is all conducted to a battery of shaker screens of fine mesh. The screenings are collected and loaded upon trucks for transport directly to cattle feeding. The screen effluent is pumped directly to head boxes on the irrigation system which distributes through a system of unlined ditches. Deeper furrows are cut in the downstream ends of the fields to prevent runoff of any excess irrigation water. (The lower portions of the field, as a consequence, produced the highest yield since they receive more water.)

Irrigation water from a separate source is available for the early part of the growing season and only later sequence crops receive plant wastewater. Some wastewater is applied to the land after early fields have been harvested. One field of mature corn was observed that had been irrigated by the wastes and it looked healthy and productive.

2i. Potato Processing Plant
Idaho Potato Division (1970 - 0.5 mgd)
Western Farmers Association
Aberdeen, Idaho

The plant processes potatoes to a frozen packaged state. The process includes washing and peeling and further preparation for french frying, mashing, etc. The waste includes the peeling in the peeling process water, culls, floor drops, and washdown water. Recently, it has put more control on the use of water and has reduced the use of water by one-half to about 500,000 gpd.

The waste is put through a clarifier, the effluent from which is directly conducted to the spray irrigation area which is about one and one-half miles from the processing area. The sludge or starchy solids from the bottom of the clarifier are filtered on a conventional vacuum drum filter, the cake from which is used directly as a cattle feed. The filtrate is returned to the clarifier influent.

Spray irrigation is carefully regulated to operate successively on each of twelve 7.5-acre plots for four hours per irrigation period. Therefore, the full plant effluent rate (0.5 mgd) is applied to each plot every other day for four hours. The area has not yet been planted but plans include seeding the site with corn and pasture grass next season.

As potatoes can be stored, the plant operates from the beginning of harvest, September, until the stored potatoes have been processed, generally through May.

3i. Celotex Corporation (1971 - 0.18 mgd)
Lagro, Indiana

The Lagro plant of Celotex was purchased many years ago from a rock wool manufacturer. Originally, the plant effluent was considered innocuous and consisted primarily of inert inorganic materials. Later as new products were added a more complicated waste evolved, but in view of the condition of the Wabash River during the early 1960's, only primary settling to remove paint pigments (chiefly kaoline) was required. Gradually the level of BOD built to 200 ppm as a starch bonding agent was added to the process but there was no pressure from state authorities until 1968. By this time, Celotex had experience with two other spray irrigation treatment systems (Pittston, Pennsylvania, 1960 and L'Anse, Michigan, 1967), both of which had been successful in dealing with effluent of similar quality.

The soil at Lagro differs markedly from the highly permeable soils at the other two sites, being a dense mixture of silt and clay which, except for a high content of organic matter, would be virtually impervious. In addition, a weathered limestone formation maintains a perched water table very close to the surface. This in turn severely limits the lateral movement of underground water. Therefore, the first requirement of a treatment system was an under-drainage system to move the water away from the area of application. This was accomplished by installing lines of perforated polyethylene pipes on 29.6-foot centers across the entire tract. Samples collected from these underdrains provide monitoring data for the system. Only COD, suspended solids and volume data must be reported to state authorities, but Celotex also maintains a record of chlorides and conductivity.

Roughly, 80 percent of the 4,000 lbs/day suspended solids are settleable and since the addition of this quantity of clay to the land would only compound the already limited infiltration capacity, a settling basin with three days' retention time was installed for suspended solids removal. Winter storage for 36 days has also been provided. Experience during two winters has indicated that this area is large enough.

The Lagro system is also fully automatic. Eight sprinklers operate from each of eight automatic valves. A clock timer activates the pumps which, in turn, activate the program timer which automatically turns the various lines off and on according to a predetermined schedule. Although the system is only two years old, there is strong assurance that the degree of water purification will continue to be within the requirement of established state and local authorities for many years to come.

Figure 22, Celotex Corporation, contains photographs of the settling tank and the treatment area.

4i. Commercial Solvents Corporation
(1965 - 0.07 mgd)
Terre Haute, Indiana

The Terre Haute plant has a variety of disposal procedures depending upon characteristics of the waste to be treated. High volume-low BOD flows are treated anaerobically-aerobically, whereas high BOD-low volume flows are handled through a land application system.

The land application system treats fermentation wastes from the production of monosodium glutamate, zinc bacitracin and riboflavin.

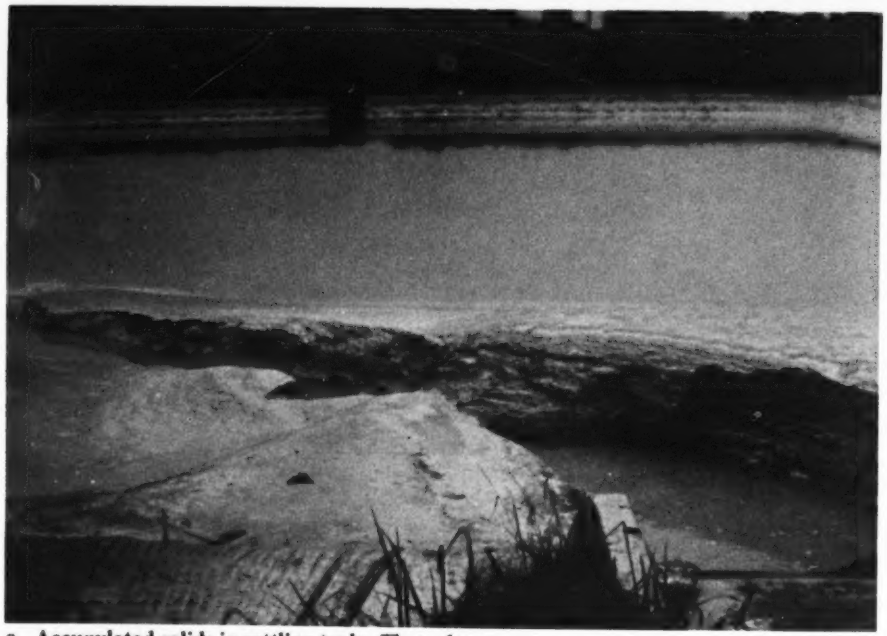
The plant is operated on a continuous basis throughout the year. The daily average of 70,000 gallons is produced, which may have small amounts of nitrogen and other chemicals. Its composition is primarily bacteria cells from the fermentation process. The BOD of the liquid is from 25,000 to 40,000 mg/l, with a 30,000 mg/l average. Suspended solids average 40,000 mg/l. The bio-mass can be as much as 100,000.

The treatment facility is operated five days a week, one shift a day. The wastes are pumped under the Wabash River to a 360-acre site immediately across the river from the plant. At the site are two 85,000-gallon storage pits. At the plant, a 120,000-gallon tank is available for emergency storage. The land is protected by a levee. Spraying takes place on a 160-acre portion of the site on generally sandy or loamy soil, although there are some clay knolls. Only about 100 acres are actually used for land application. The balance of the plot (200 acres) is farmed and it is somewhat lower and has clay soils.

Adjacent to the levee, a 100-foot buffer has been maintained. On the other edges of the sprayed plot, a 200-foot buffer is maintained to minimize the possibility of runoff to adjacent land.

The facility is set up with permanent headers which are generally spiraled steel pipe. Aluminum headers were used, but severe corrosion problems developed; 6-inch steel pipe is used for headers and 4-inch lines are used to the spray head. Perhaps because of the handling and draining, headers have not shown any corrosion failure.

Rainbird sprinklers are used. Each sprinkler covers a one-acre plot. The rate of application has been varied through the years. Initially, 5,400 gallons per acre in 10 hours were applied. The plot was then rested for two weeks. Three cycles of application were made and then the plot was allowed to rest 90 days. Through the years, operating procedures have changed. At the present time, the application is continued until runoff appears. This may involve spraying for three days, approximately five hours per day. The plot is then rested from one to two weeks. After about three such cycles, the area is rested



a. Accumulated solids in settling tank. Three days retention provided

b. Reed Canary Grass on treatment area. At center of photograph, shredding is in progress.

FIGURE 22
CELOTEX CORPORATION, LAGRO, INDIANA

from 30 to 90 days. Some plots again can be irrigated for only two hours and at most for five hours. Spray nozzles have been adjusted so that at the present time the rate is 60 gallons per minute, or approximately 3,500 gallons per hour. Between 3 and 10 acres are irrigated each day, averaging approximately 5. In the wintertime, fewer acres are watered, and the operation is moved close to the holding basin upon an abandoned municipal landfill. This tends to minimize the manpower requirements for maintaining and draining the system. Headers are mounted above the ground on wood trestles or concrete blocks. Drains are provided very frequently to minimize wintertime operating problems.

Initially, the area was posted with signs. However, experience showed that signs were destroyed by hunters. Inasmuch as aluminum pipe is very vulnerable to damage, it was decided to not post the property and therefore, their problems have decreased.

Natural drainage sloughs through the area have been contoured to allow drainage to the holding basin. From the concurrence of the sloughs, return flows are pumped back to the holding pits and then reapplied. The sloughs are shallow enough that only overland flow reaches them. Two men are employed to run the facility and the amount of equipment that is on hand.

The heavy solids load results in the virtual elimination of vegetation during the spray cycle. If the flow is applied to fall on bare ground, the bacteria cells appear to become classified and seal the surface. The experience of Commercial has been that when this land is plowed, this classified layer is buried and will act to seal the ground at a level beneath the surface. Therefore, the company is experimenting with two different means of protecting the ground surface. On one acre, it has placed bark at a cost of approximately $200 per acre. On the second plot, it has placed straw. Both means have permitted an extension of spraying time.

At the time the site was visited, 7 inches of rain had fallen in the preceding week and all the ground in the area was saturated. Some ponding was observed, although there were no objectionable odors at the site. Part of the site was originally covered with forest, and because of the heavy application of water, the trees are now dead. Some effort has been made to knock over the trees and where this has been done, they have been left on the land to provide some shelter and breakup of the sprinkler flow. If viewed from an aesthetic standpoint, the area would appear to a bystander to have been killed. However, portions of the spray irrigation area have been taken out of such use and farmed with no apparent deleterious effects on the crop.

It appears that Commercial Solvents, because of the critical features of the fermentation wastes, has been willing to provide engineering on a continuing basis to ensure that the facility was properly operated. This is the only Commercial Solvents plant that has a land application system. The method might be appropriate at others; however, Commercial Solvents indicates that suitable land is not available.

5i. Chesapeake Foods Poultry Processing Plant (1972 - 0.55 mgd) Cordova, Maryland

Chesapeake foods operates the poultry processing plant at Cordova, Maryland, under a lease from Allen's Hatchery, Seaford, Delaware. The lease includes the plant and equipment, including the land application system.

The poultry plant has been in operation for almost 15 years; however, it was closed during most of 1971 and has been operated by Chesapeake Foods for less than a year. The plant processes broilers and fryers for sale to retailers.

Reportedly, land application has been used at this plant for about 15 years; however, the current site has been in use only since Chesapeake Foods took over the plant operation in January 1972. A new automatic sprinkler irrigation system was installed by the owner, prior to leasing the plant to Chesapeake Foods.

Treatment

Wastewater from poultry processing lines flows by gravity to a screening plant where solid materials (poultry, viscera, heads, feet, etc.) are separated on a vibrating screen and elevated into a large hopper semitrailer. Fats, skimmed off at a clarifier tank, and feathers are also separated and, along with other solids, sold for processing into a poultry food additive.

After passing through the screening plant and clarifier (skimmer), the wastewater is pumped into an elevated storage tank or into a storage lagoon. The storage lagoon has an estimated capacity of about two days' production of wastewater. At the time of this visit, the lagoon was nearly dry and was overgrown with vegetation. After screening and skimming, the wastewater is relatively clear and has no objectionable odor.

Application

The elevated tank provides gravity feed to pumps which supply the application site, located about one-half mile away. The force main is an 8-inch pipe with a 6-inch distributor main and 3-inch laterals with 1-inch risers. There are six automatically controlled laterals and the system is programmed to operate one lateral each day. This provides six sections in the spray field, with each being used every six days. Within each section, the spray pattern changes every 15 minutes according to a preselected program. The spray equipment and controls are products of the Automatic Sprinkler Corporation.

The spray field consists of approximately 40 acres of farmland which has been sowed with Kentucky 31 Fescue. At the time of the visit, the ground cover was about 12 inches high with no evidence of burning or discoloration. Maintenance of the ground cover is limited to mowing periodically to maintain the height between 12 to 24 inches. At present, no hay is produced, but it was reported this was being considered. A 15- to 20-foot buffer zone around the perimeter of the spray field separates it from the adjacent fields of corn and soybeans. No security precautions were observed.

A small creek borders the lower edge of the spray field, and runoff, if any, goes into this creek. No problem was reported in maintaining acceptable BOD levels in this creek.

The University of Maryland operates an experimental plot adjacent to the processing plant and utilizes wastewater for irrigating various crops on an experimental basis.

6i. Celotex Corporation (1966 - 0.6 mgd) L'Anse, Michigan

In November 1957, experimental work in L'Anse, Michigan, was undertaken to demonstrate that a snow cover can protect the soil from freezing and that if water could be discharged under the snow, it too would remain unfrozen and percolate into the soil. Following a successful demonstration, a full-scale treatment system was installed during 1958-1959 to be ready for factory start-up in 1960.

It became evident at the outset that the technique would not work as planned, first, because suspended solids migrated to the end of the lines and caused plugging of the orifices, but even more importantly, the water temperature was nearly 140°F so that the soil was literally pasteurized and the vegetation was killed. After unsuccessful attempts to remedy the situation, the "under- the-snow" technique was abandoned and conventional irrigation sprinklers in the woods near the original site and a storage lagoon were installed for winter use. The second installation was only slightly more successful than the first, chiefly because the area covered by the sprinklers was much too small, but also because a high water table seriously limited the lateral movement of water underground.

Finally, in 1966, a third installation was made on a 100-acre tract of sandy soil which ranged in depth from 6 to 14 feet. In order to augment the natural drainage from the field, lines of perforated pipe were installed at 600 foot intervals. However, in practice, these pipes remove only a small faction of the total water applied. The latest system, which is now in its seventh year of operation, is fully automatic and is operated by one man, part time. The primary duty of the operator is the repair of sprinklers which after five years of operation are now becoming worn.

The sprinklers at Celotex have been installed in an overlapping grid pattern with each sprinkler covering an area of 10,000 square feet. Twenty-six sprinkler lines with 14 sprinklers each are controlled by automatic valves. Each line discharges 308 gpm. There are 364 operating sprinklers covering a wetted area of 83 acres. The system was originally planned for an application of 0.53 inches per acre per day, but in practice the operating time has been extended to apply 0.8 inches per day - 1.9 mgd.

The effluent from the Celotex plant originates from the manufacture of cellulose insulation board and from fireproof mineral board. The biodegradable constituents of the former are hexose and pentose sugars while the latter contains a starch bonding agent. The flow from the two sources is nearly equal. After leaving the factory, the effluent is pumped to a storage lagoon with 120 mg capacity which provides winter storage as well as pretreatment. As the effluent flows through the lagoon, biological action reduces the BOD by about 50 percent to approximately 1,200 ppm.

From the storage lagoon the water is pumped at high pressure to the treatment area 2.5 miles south. Ground cover on the treatment field is Reed Canary Grass which has never been cut. There is now a thick blanket of decaying vegetation on the soil surface which provides an excellent habitat for microorganisms. Since both of the two sources of effluent are low in plant nutrients, a regular soil-sampling program is maintained to assure an adequate supply of nitrogen and potassium, but no other monitoring of the soil or groundwater is being maintained.

The Michigan Water Resources Commission has imposed a requirement upon Celotex: that there shall be no deterioration of the water quality of Ogemar Creek - a trout stream which flows along the southern boundary of the treatment area. Monitoring of this creek above and below the treatment area has shown no change during the past seven years.

7i. Stokely-Van Camp (1953 - 0.8 mgd) Fairmont, Minnesota

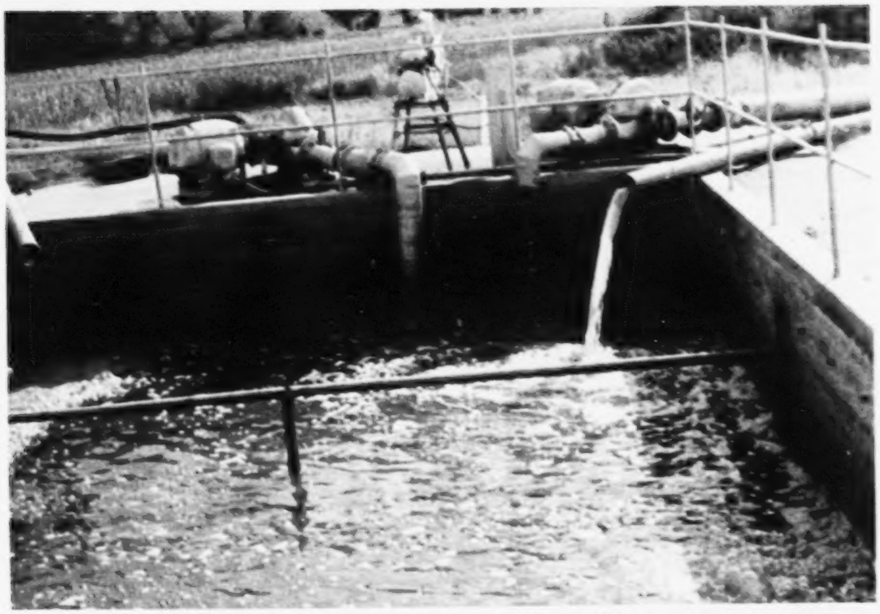
The Stokely system at Fairmont is unique. All of the water applied is lost to the atmosphere by evaporation or evapotranspiration. Little, if any, penetrates the soil below the root zone and any runoff is collected and resprayed. Accordingly, the application rate is very low (0.1 inches per day), and the acreage demand very high: 400 acres for 2.0 mgd in summer. The system evolved from the early 1950's and has undergone a threefold changeover in equipment.

Initially, conventional portable pipe was used with Rainbird No. 70 nozzles. However, the labor required to move the lines under conditions of very low-rate application was prohibitive. Gradually, the portable system was replaced by boom-type irrigators which were then modified to provide greater atomization of the spray and the axles were extended to resist overturn. These, too, were demanding of labor. Finally, a fixed tower was designed which was equipped with ten 30-gpm fog nozzles and operated under very high pressure. On windy days, the spray drifts a quarter-mile or more with very little reaching the ground. Accordingly, in order to avoid wind drift to neighbors' property, the southern sprinklers are not used when high winds blow from the north. As a general rule, the towers are located on 500-foot centers.

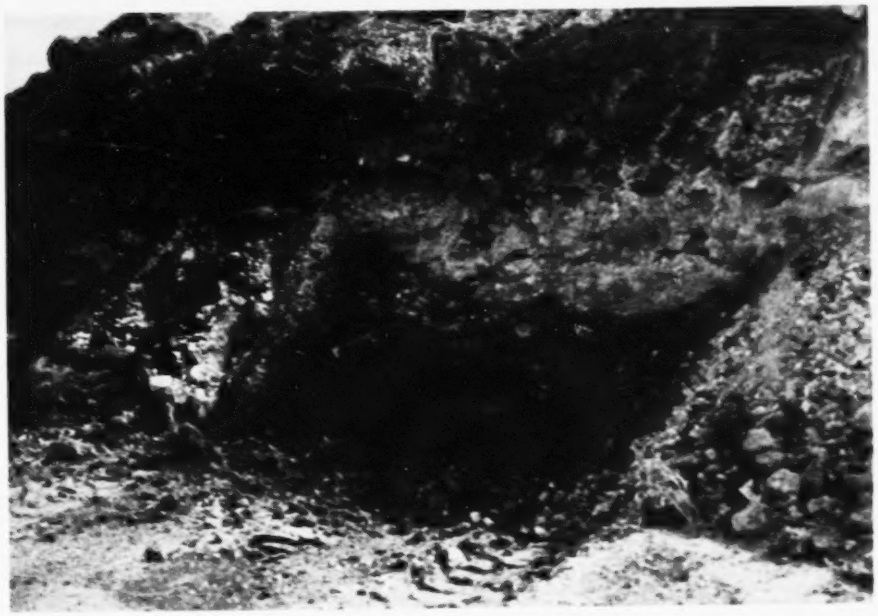
Figure 23, Stokely-Van Camp, Fairmont, Minnesota, contains photographs of the irrigation system

The Stokely system operates from mid-April to mid-November, with storage to receive the small quanity of water discharged during winter. Some odor problems are evident during the spring turnover, but the situation lasts for only a week or 10 days, and since the installation is remotely located from dwellings, there has been no complaint. The lagoons are emptied by mid-June when pea harvest begins.

The operation of the Stokely system is well regulated. It can be considered as a unique example of adopting a hostile, natural situation to a specific problem.



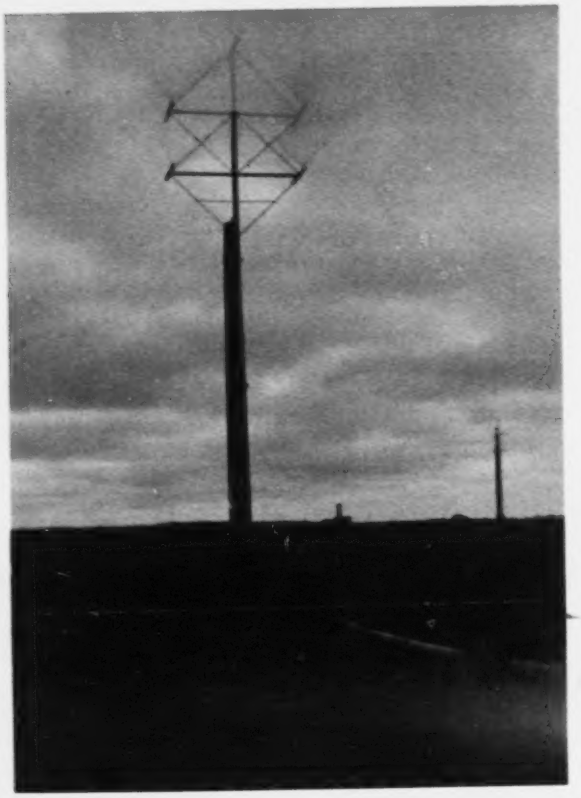
a. Two 1,200 gpm pumps pump to the sprays. Part of the water is bled off to balance the capacity of the sprays and minimize on and off cycling. Runoff water is also returned for reapplication

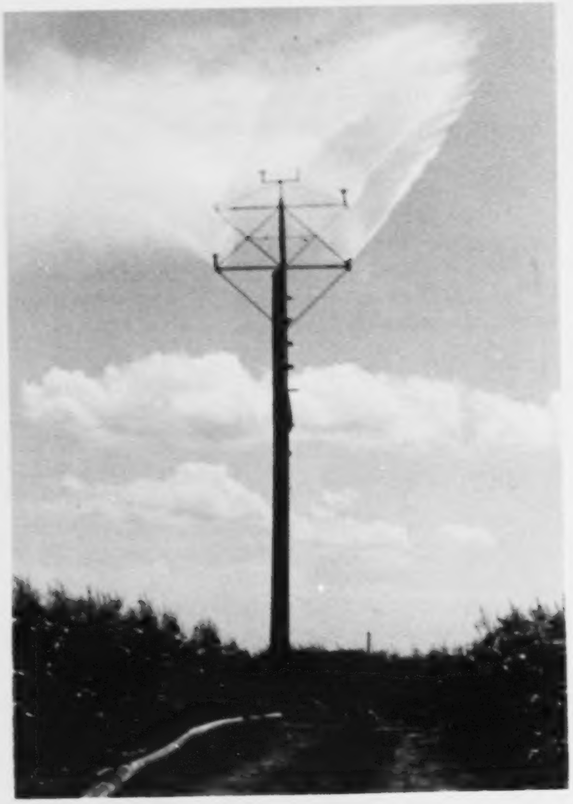


b. Black gumbo clay is underlain with yellowish grey clay. Little water penetrates the root zone

FIGURE 23
STOKELY VAN CAMP, FAIRMONT, MICHIGAN

c. Towers are designed to discharge fog from ten 30 gpm nozzles at fixed locations (right side)





d. On a windy day the spray drifts for a quarter mile or more. The corn crop is shown. (left side)

FIGURE 23
STOKELY-VAN CAMP, FAIRMONT, MINNESOTA

The entire disposal area is planted to cash crops - corn, peas, and brome grass. The first two yield profitable returns, but the market for hay has dwindled in that area of Minnesota just as it has farther north in Michigan, so that hay farming is no longer profitable.

The records maintained by the Company are sparse and consist largely of a BOD evaluation of any water which escapes in the storm drainage system. Soil analysis for a fertilizer program is maintained but otherwise there is no record of the buildup of salts nor the fate of nitrogen, phosphorous, etc. However, because of the exceptionally low rate of application and the cropping program, it is not likely that much escapes.

8i. Michigan Milk Producers Associates
(1964 - 0.25 mgd) Ovid, Michigan

Michigan Milk Producers is a marketing group whose primary function is the supply of fluid milk to the Detroit market. During the latter part of the business week the demand for fluid milk increases while a surplus exists from Monday through Wednesday. During the surplus period, the factory at Ovid dehydrates the market excess. Therefore, the supply to the factory is highly variable. The wastewater, however, is entirely free from wash water so that the quantity remains fairy constant at 0.25 mgd.

The soils are deep sand with very high permeability. The area available for treatment - 95 acres - is located in the bottom of a shallow valley, with a small stream bisecting it, and a depth to water table of not more than six or eight feet. Ordinarily, one would expect the floodplain soils to contain a large percentage of silt and to be of relatively low permeability. However, this is not the case and the Company is able to apply water at the rate of 0.30 inch per day on a continuous basis.

The effluent from the factory flows by gravity to a wet well at the treatment site, approximately two miles away. From here it is pumped to a 40,000- gallon storage tank - actually an old clarifier which was part of an abandoned conventional treatment works. At the clarifier, milk fat which has been partially emulsified floats to the surface and gradually decomposes. The clarified water is pumped periodically from beneath the fat blanket and discharged at high pressure from 300 gpm sprinklers, scattered throughout the 95-acre tract. About half of the 95 available acres is being used. The sprinklers operate intermittently to pump out about 40,000 gallons of accumulated water and then shut down while the surge tank refills.

There is no predetermined operating schedule. The operating sprinklers are rotated whenever they appear to be overloaded and local flooding may occur. However, it was reported that there has been no complaint from the state authorities.

The site is visited each shift by operating personnel. The dominant species of vegetation is Reed Canary Grass which is seldom, if ever, harvested, and large areas are completely wild.

9i. Simpson Lee Paper Company
(1971 - 3.2 mgd) Vicksburg, Michigan

The Vicksburg plant of the Simpson Lee Paper Company specializes in the production of small orders of very heavy quality paper from preprocessed paper stock. This is a finishing mill, as contrasted to a pulp mill. The process is "batch," as opposed to "continuous," and involves the use of lead and cadmium in various formulations. When these heavy metals are in use, the wastewater is routed to a "leeching area" - 20 acres of confined swamp containing several feet of peat soil. As the water filters through the organic soil, an ion exchange takes place which results in the containment of pollutants upon the humus micelle, thus removing the heavy metals from the water, which eventually finds its way into the groundwater or evaporates to the atmosphere. It is recognized that this containment technique is not a permanent solution to the problem, but it is estimated that the adsorption capacity will last for another 20 years.

During periods when heavy metals are not in use or when their quantity is minimal, the effluent is first clarified to remove 12,500 lbs/day of settleable solids which are then hauled to a landfill. The clarified effluent is routed to an 80-acre spray irrigation site, consisting of four 20-acre plots. Each plot receives water for 24 hours at the rate of 5.9 inches per acre per application and then is rested for four or five days according to the factory production schedule. The soils of the area are exceptionally well suited to this type of operation and could probably handle two times the present rate. Alfalfa was chosen as a crop because it would tolerate high irrigation levels and still produce maximum yields. However, the high moisture condition has resulted in much of the alfalfa being naturally replaced by hydrophytic species.

The influence of modern waste treatment regulations is very much evident in the monitoring program which is designed to reflect long- and short-term change in soil and groundwater quality, as well as a quantitative and qualitative evaluation of clarifier efficiency and the input to the final treatment works. In fact, this system is so well monitored that portions of it could be used to determine the fate of mineral constituents of the waste - nitrogen in particular - under variable rates and frequency of application, as an exercise in basic research.

Physically, the system design is simple and appears expensive to operate. On the other hand, the capital cost is low, which may in itself justify the short-term, higher operating cost.

One point which has not been made clear is the fate of the total nitrogen which is applied at the rate of 125 lbs/day and is eventually converted to NO^3 nitrogen. This results in an annual application of 4,300 lbs/acre per year which is considerably more than plants can utilize. However, monthly tests on nitrate level in the test wells have shown an actual decrease as compared to the three months of tests prior to spray irrigation.

10i. Green Giant Company
(and other sites)
(1949 - 1.2 mgd) Le Sueur, Minnesota

The Green Giant Company operates several canneries where land application is used. The effluent varies with the vegetable being packed; however, other than salt, almost no chemical additives are added other than some detergents. Basically, the polluting products are soil products and portions of the vegetable being canned. All flows are screened and then applied raw. The effluent may be as high as 2,000 mg/l BOD. The canning season at each of the Company's plants depends upon products being canned; peas and corn are processed approximately 100 days - from mid June to October. Corn is only processed approximately 60 days - August to October.

The plant at Le Sueur uses percolation beds and was not investigated.

At Glencoe, a spray irrigation facility was recently abandoned and a stabilization pond capable of holding a year's flow was installed. Glencoe is within an area of heavy clays. Even though the fields were tiled, the discharge from the tiled field required treatment and therefore, it was more economical to treat the return flow than to treat the return drainage. The flow is 2.5 mgd. Peas and corn are packed.

A plant at Montgomery uses overhead spray. Peas and corn are canned. The flow is 120 mg in 100 days, or 1.2 mgd; 360 acres are used. To obtain this much usable land, 660 acres were purchased or leased. The balance of the land is swampy. Application is approximately 10 inches a year. The area is entirely grassed. No security fences are provided.

The plant at Blue Earth packs peas and corn. The flow is 0.5 mgd; 105 acres are used with 160 gross acres.

The application rate is 12-15 inches per year. The effluent contains 2,000 mg/l BOD and is not rich in nitrogen. The phosphorous level is 3.75 mg/l.

A plant at Winsted packs only corn. The flow is 0.4 mgd. It operates 60 days; 80 gross acres are used with a net area of 70 acres.

A plant at Cokato packs corn. The flow is 0.5 mgd; during a 60-day season the application rate is 10 inches per year.

In Wisconsin there are four plants, three of which use spray irrigation.

The plant effluent at Beaver Dam goes to the municipality, inasmuch as green beans are packed which have extremely weak polluting load flows: 1 mgd for a 90-day season. Plants at Rosendale, Ripon, and Fox Lake are spray irrigated. Because of soil characteristics, only 20 inches per year are applied during the 100-day season. All plants pack peas and corn and have a flow of about 1 mgd. The plant at Ripon is distinctive inasmuch as 80 acres are used in four plots. Two plots are idle; one is being sprayed and one is being used for pasture. An electric fence separates the four plots and cattle are rotated regularly. The land is well drained.

A plant at Belvidere, Illinois, uses spray irrigation and high-rate percolation. During the summer, peas and corn are packed and then repackaging of bulk frozen foods takes place in the winter as well as rice processing. During the period of May to November, spray irrigation is used. During the balance of the year, percolation ditches with an 8-foot center, 2 feet wide and 9 inches deep are used. Ditches are filled serially. Maximum flow is 2 mgd and 0.2 mgd in the winter. A total of 60 inches per year is applied to the gravel soil. Packing BOD loadings are 300 to 400 mg/l. BOD in the winter is 1,000 mg/l when rice is being processed.

In the State of Washington, the Dayton plant uses spray irrigation. The flow of 1.5 mgd irrigates peas and asparagus. The Waitsburg plant uses spray irrigation at a rate of 2 mgd; peas and green beans are packed.

In Idaho, the Buhl plant uses ridge and furrow irrigation to irrigate corn. In Fruitland, Maryland, spray irrigation is used on grass planted upon sand at a rate of 60 to 100 inches per year during the period June 1 to October 1. The flow is 0.75 mgd and green beans and peas are packed.

Peas require a salt flotation process to classify sinkers from floaters. Salt in the flow injures alfalfa and thus only salt-tolerant grasses are irrigated.

At Montgomery, 0.18 inches per hour is applied for a period of five to eight hours per day every 7 to 10 days. The direct cost of the operation is $28,000. Indirect cost is $40,000 to $48,000, including cost of the land. Total cost of disposal is approximately $0.75 per thousand gallons.

At Montgomery, the acreage is cut for hay by farmers early in June at no cost to the Green Giant Company. After that, grass is mowed weekly and allowed to stay on the land.

The land is valued at $400 per gross acre, or $750 per usable acre. The capital improvements run about $200 per acre used. Topography allows utilization of just over one-half of the gross acreage. In some cases, land is leased and the owner retains a minimum acreage at his residence site. The land is rolling and gives the appearance of a golf course. No storage is provided.

The wastes are screened on an 18 x 18 mesh, with 0.0356-inch openings.

11i. Gerber Products Company
(1950 - 1.5 mgd) Fremont, Michigan

The treatment system of the Gerber plant in Fremont is one of the very old systems in the Nation. The disposal area is upon a deep layer of sand. The design reflects early standards with very little change since its original construction in 1952. There has also been little change in the modus operandi, with the scheduling based upon experienced observation rather than scientific evaluation. As with all of these very old installations, little was known originally about the limits and capabilities of the technique and the operating routine was developed through trial and error. Once a successful technique had been developed, there was no need for further exploration and the operation has continued unchanged for many year. However, unlike many of the older systems, the Gerber installation has not suffered from physical degeneration. The equipment is in good condition, the grass is mowed regularly, and a good appearance is maintained.

During the early days of operation when groundwater contamination was of great concern, numerous samples were evaluated. However, when nothing turned up, which was then regarded as deleterious, the sampling was discontinued and the records are not now available. An exception to this are samples which are withdrawn from a water well within the treatment area. This water is tested for coliform bacteria only a few times a year and the results have been negative. Gerber has recently started regular tests of the groundwater to establish any long-term trend in the levels of nitrite, nitrate, and phosphorous.

Although Fremont is located in a fairly cold climate, year-round operations continue, and the storage lagoons are used only occasionally. During severe weather, spraying is continuous and an insulating ice cake is formed, preventing soil freeze-up. Continuing spraying of relatively warm (60°F) water channels through the ice and percolates into the unfrozen soil. During these periods, the degree of purification is questionable, but theoretically, biological degradation continues in the unfrozen sandy soil. It is surprising that the grass survives long periods of submergence under ice. Experience elsewhere has shown that many species are killed. The dominant species at Fremont is quack grass.

A 4,000-gallon collection tank at the farm receives the wastewater from the 10-inch pipeline. The water level in this tank controls the starting and stopping of 40-hp and 60-hp pumps feeding water into the distribution system. The distribution system consists of an 8-inch cast iron main with valved risers at 130-foot intervals which supply 4-inch aluminum pipe laterals perpendicular to the main. The main is buried below the frost line but the laterals are surface-mounted and may be disconnected and moved around to spray in different areas of the farm. Each lateral has five or more tees for sprinkler heads at 120-foot intervals.

Buckner No. 692 Super Irrigator Nozzles with a 5/8-inch orifice are used and will cover a 210-foot diameter circle while delivering 81 gpm at 60 psi pressure.

Extremely light loadings probably account for the success of the system since the operating routine is visually controlled and problem areas may occasionally develop.

Usually, the problem areas develop after a line has been heavily used for several weeks and manifest themselves by the formation of a black slime which develops in shallow potholes. When this occurs, the infiltration is reduced and there is no runoff. At this point, the flow is moved to a new location and the damaged area is subsurface-plowed to aerate the soil. The black slime is a combination of algae and mold growths which can be prevented if there is extensive reserve capacity and careful field suspension.

The land application area is a 140-acre typical Michigan sand farm, normally good only for tree farming but excellent for spray irrigation as the overlay is approximately 50 feet of sand and sandy loam The terrain is fairly flat, with natural drainage toward a couple of potholes which have been developed into lagoons for winter storage when the weather is too severe for spraying. Ninety acres of the farm are equipped to receive water but normally only about 60 acres are used.

In the beginning, Gerber experimented with various cover crops and trees with the hope of raising them for profit. Although growth rates were outstanding, the effort has been abandoned, except for hay cropping, as it interfered with the disposal of water. Ice damage to the trees during wintertime spraying spoiled the idea of forest or wood lot development. Through the process of natural survival, a cover crop of various weeds but predominately quack grass has developed. The fields are mowed fairly short to limit growth and consequent buildup of thatch on the surface. As an experiment, a neighboring cattle feeder collected the grasses for hay silage. The grasses test high, at 25 percent in protein level.

The flow rate varies seasonally from about 600,000 to 1,240,000 gallons per operating day. The suspended solids vary from 200 to 3,000 mg/l, and the BOD from 800 to 3,000 mg/l. The pH is close to neutral most of the time, but may vary from 4.3 to 11 - depending on activities at the plant. Variation of the pH has produced no noticeable damage to cover crop vegetation.

Costs

The original investment in 1952 for installing the system was about $90,000. Since that time Gerber has added $50,000 worth of capital improvements. Operating costs are currently about $4,000 per month, which include charges for haul-away of the solids removed by screening.

12i. H. J. Heinz Company
(1955 - 1.3 mgd), Salem, New Jersey

The H. J. Heinz Company in Salem, New Jersey, is a major producer of tomato products, mainly ketchup. Fresh tomatoes are processed during the months of July, August, and September. The resulting tomato concentrate is then stored for further processing as ketchup during the remainder of the year.

The land application system is used only during the fresh tomato processing season, July-September. At all other times, the industrial waste is processed by the Salem Municipal Sewage Treatment Plant. The municipal plant does not have sufficient capacity to treat the liquid wastes produced during the fresh tomato season.

Land application was started in 1955 and the initial cost was about $100,000. Major capital costs since 1955 include $50,000 for a new 10-inch force main in 1970, and $40,000 for new irrigation lines in 1971-1972.

The choice of land application over more conventional treatment methods was based on economics and was influenced by the possibility that the Salem Municipal Treatment Plant might be expanded to handle plant wastes on a year-round basis at some time in the future.

Treatment

Treatment of the wastewater includes screening to remove cull tomatoes, seeds, stems, skins, etc., and processing through a cyclone desander to remove sand, grit and seeds. Screenings are removed by truck for disposal at a sanitary landfill. The liquid effluent is pumped through a 10-inch force main to the land application site approximately one mile away.

A large percentage of the liquid waste is the flume water used to transport the tomatoes within the processing plant. Future plans include a system for reusing the flume water and this would greatly reduce the volume of liquid wastes.

Another source of liquid wastes is the runoff from the concrete-paved unloading area at the processing plant. A considerable amount of wastewater results from flushing these paved surfaces and from stormwater during rains. Flow from catch basins in the unloading area is processed as industrial waste during the fresh tomato season.

The pH of the wastewater was reported to be 4.3 due to recent installation of cook tank vent scrubbers. No treatment is being conducted to raise the pH, although some maintenance difficulties were reputed to be caused by the highly corrosive effluent. Feasibility studies are presently being conducted to determine suitable methods for controlling pH at proper levels.

Application

The application area consisted of low-lying marginal land adjacent to the tidal marsh. Soil conditions were reported as sandy silt with areas of clay and heavy silt loam. Groundwater was reported to be 4.5-11 feet below the ground surface.

At present, it was reported some 22 acres were used as a spray area. This area is divided into six sections which are alternated, based on visual observation of ponding. The application rate is approximately 0.8 inch/day or 6 inches/week. A holding pond provides emergency storage for approximately one-half day's wastewater production. A 15,000-gallon wooden tank serves as a wet well for a float-actuated diesel pump. The spray system consists of a 6-inch distributor main with 4-inch laterals and 1-inch risers equipped with 17.6 gpm Rainbird sprinkler heads.

Vegetation in the spray area is a mixture of sea myrtle (a low, woody shrub), honeysuckle and Reed Canary Grass along with wild marshgrass and native weeds. At the time of the inspection, the vegetation was four to five feet high, with no cultivation or mowing other than clearing vegetation that interfered with sprinkler operations.

Considerable discoloration and burning of vegetation was noted in the spray area. Reportedly, this was due to the low pH of the wastewater and may have been aggravated by a recent increase in the temperature of the wastewater. During the nine months (October-June) when the spray area is not in use, the vegetation reportedly recovers its foliage and normal color rapidly with no lasting adverse effects. Rabbits, muskrats, and other wildlife reportedly abound in the spray area.

Twelve test wells about 5-feet deep were being used to sample groundwater in the spray area.

13i. Hunt-Wesson Foods, Inc.
(1961 - 3.0 mgd) Bridgeton, New Jersey

The treatment system of Hunt-Wesson Foods in Bridgeton, New Jersey, is designed primarily for tomato wastewater which flows to 44.1-acres of a 70-acre application tract at the rate of 3.0 mgd. This results in the exceptionally high rate of application of 2.5 inches per wetted acre per day. Actually, there are three systems within 20 miles of each other in southern New Jersey (Seabrook and Heinz) where the soil formation permits exceptionally high rates of application. At Hunt and Seabrook this unusual situation is brought about by an open sandy soil, combined with a large difference in elevation so that the water moves quickly from the area of application. At Heinz, the soil is sandy, but the elevation differential is only 12 feet. The Heinz system is successful because it is located on a rounded peninsula so that water can escape from 80 percent of its circumference.

The Hunt system is well managed, with a full-time operator who changes the lines on a regular schedule. The piping is on the surface, with large sprinklers located on 160-foot centers forming a solid set pattern. Unfortunately, the laterals do not follow the ground contour so that they drain through the lowest sprinkler when the pump is off.

The records maintained by the Company are incomplete and do not reflect changes in the quality of the groundwater or the buildup of salts in the soil. During the tomato season, a trickle of water flows overland from the field and drains into the soil of an adjacent field also owned by the Company. Periodic checks of this runoff include a rather complete analysis. The quantity is slight and the water rapidly disappears into the soil.

The vegetation is totally wild as it is at Seabrook and Heinz. However, the owner has cut the brush and shrubs in order to make all sprinklers visible to the operator. This has substantially reduced the incidence of undiscovered sprinkler malfunctions and greatly improved the efficiency of the system.

There is no attempt to harvest the grass although in the New Jersey area there is a ready market for hay of any quality.

Aside from the exceptionally high rate of application, the only other unique feature of this system is joint ownership. That is, Hunt-Wesson and P. J. Ritter Company joined to construct a system to serve them both. Hunt-Wesson assumes the management of the system and back-charges Ritter on a gallonage basis. Both companies operate 12 months per year and both pack tomato in about equal volume.

14i. U.S. Gypsum Company
(1954 - 1.2 mgd) Pilot Rock, Oregon

This plant produces fiberboard, hardboard, insulation board, and acoustic ceiling and wall covering, etc. The waste applied to the land by the irrigation system is effluent from an Oliver Saveall or fiber recovery unit.

The waste is pumped approximately a mile to a 40-acre holding pond within a fenced area which includes the irrigated pasture area and a portion informally designated a game reserve. Two movable sprinkler headers are fed by a pump taking suction out of the pond. These headers are moved twice a day and water is applied directly by pump suction from the pond. Header moving requires two hours, so that there are two sprinkling periods of 10 hours each day. It takes 14 days to irrigate the entire pasture area and then the cycle is repeated. The irrigation season extends for about 270 days per year depending upon the duration of freezing conditions. This requires that the pond be drawn down by late fall to permit flow storage for the entire winter.

The pasture land looked in good condition and the grazing cattle seemed to do well. Cattle sometimes drink the water in some low spots rather than go to the watering troughs fed by well water.

15i. Weyerhaeuser Company Springfield Plant (1959 - 0.5 mgd) Springfield, Oregon

The plant treats paperboard black liquor and normally discharges a secondary effluent to the McKenzie River but supplements with ground application of the effluent during the low river flow period. At the time of the visit the application equipment had already been removed from the field for water storage as the irrigation season was over. The field is on a gentle slope bordering the river. High river stage inundates or nearly inundates lands, thus the practical application season is limited.

Although the site is under company control, arrangements have been made for the grazing lessee to alternate the banks of sprinklers as best suits his grazing needs.

16i. Musselman Fruit Products (1941 - 0.205 mgd) Pet Milk Company Biglerville, Pennsylvania

Musselman Fruit Products, a division of the Pet Milk Company, is the principal industry in the town of Biglerville, Pennsylvania. Located a few miles north of Gettysburg, Biglerville is a small town in an agricultural area of many orchards. Although primarily known for its apple products, Musselman also processes other fruits, tomatoes, and canned drinks. The plant operates all year; however, the labor force is reduced during the off-season (January-June).

The spray irrigation method of wastewater disposal has been used at Musselman since about 1941. Prior to that time, trickling filters (Ryan type) were used; however, the filters could not supply the required capacity and spray irrigation was chosen primarily on the basis of economics.

Treatment

Treatment consists of screening and chemical additives for control of pH and odor. The screening plant is located adjacent to the spray irrigation site. The wastewater is screened by a rotating screen and a vibrating screen. During the visit, tomatoes were being processed and the screening consisted of cull tomatoes and tomato skins and seeds. The screenings were hauled away by truck and were disposed of at a sanitary landfill or by spreading as a top dressing on orchard land.

The effluent from the screening plant flowed into a settling lagoon which also served as a wet well for the pumps supplying the irrigation system. The screening plant effluent was monitored by an automatic pH measuring device and sodium hydroxide was being added to adjust the pH from its normal range of 4.3-5.8 to a range of 6-9 prior to spraying. It was reported that vegetation in the spray irrigation areas was sensitive to pH and showed dramatic evidence of burning when pH was low.

Sodium nitrate was being added at the settling lagoon for the primary purpose of odor control. Although there was a pungent odor at the screening plant, no odor was detected at the settling lagoon or in the spray area.

Disposal Considerations

The choice of land application was made about 1941, when the trickling filters would no longer handle the wastewater produced. Apparently, land application was chosen on the basis of economics. The receiving stream, Conewago Creek, is not large and direct discharge of untreated waste was not possible, even in 1941, due to lack of any great diluting effect in the receiving stream.

The area selected for land application is marginal pasture land which was already owned by the Company and required no relocation or zoning changes. It is located approximately one-quarter mile from the plant and is served by an underground pipeline. The USDA soil classification is ABA, Abbottstown Silt-Loam, with a slope of 0-3 percent, bedrock at 2-5 feet, and a water table ranging from 1-1/2-3 feet in the lowest area. Soil applicability for drainage, absorption and adsorption ranges from excellent to poor.

The spray area is served by a 4-inch aluminum pipe with conventional agricultural-type spray heads. The application area is divided into three separate areas of 19, 17-1/2 and 13-1/2 acres, respectively. Ground cover in the spray areas was originally Reed Canary and Kentucky Fescue; however, native weeds appear to be plentiful now.

Each of the spray areas has an interceptor ditch where runoff is collected and returned to the lagoon system for recirculation or discharge, depending on the availability of storage space. The lagoon system consists of eight lagoons plus an emergency storage lagoon. The total area devoted to the lagoon system was reported as about nine acres. Wild ducks, muskrats and turtles use the lagoons but no fish have been stocked. The lagoon system is designed for gravity flow through an outfall at the receiving stream.

Operations Maintenance

One man per shift operates the screening plant and the spray irrigation system. Some difficulty was reported with spray heads clogging and several were observed operating improperly.

The spray application plan is based on two days of application and four days of rest for each of the three spray areas, in turn. Since the three spray areas are of different size, application is not uniform. Although no application rates were specified, it is estimated the maximum application rate was about 2 inches/acre/week, assuming two days' production of wastewater was applied to the smallest spray area each week.

The spray application is operated year-round as long as the spray heads remain unfrozen. This results in spraying frozen ground during the winter and a resulting ice buildup on the ground and vegetation in the spray area.

The ground cover was originally planted in the spray areas is Reed Canary and Kentucky Fescue. No mowing or cultivation has been done and much of the original planting has been taken over by weeds. At the time of inspection, the vegetation was quite thick and averaged about three feet in height. No attempt has been made to utilize the spray area for any type of crop production.

17i. Howes Leather Company
(1972 - 0.015 mgd) Frank, West Virginia

Pocahontas Tannery, a subsidiary of Howes Leather Company, is located in the community of Frank, West Virginia. The tannery has been in operation since about 1900 and its principal product is sole leather.

The tanning process originally used oak bark as the source of tannic acid and this is the reason the tannery was originaly located in this heavily forested region. In recent years, the oak bark method has been replaced by a tanning solution made from a vegetable extract imported from Africa and South America.

The tanning process requires large quantities of water; however, only a small portion of the wastewater is processed through the land application system. This wastewater, called "spent tanning solution," has a pH of 4 to 5 and a very dark brown "coffee" color. It also has the pungent odor typical of the tanning process. Daily production of the spent tanning solution is about 15,000 gallons.

The bulk of the wastewater is treated by settlement, aeration, and storage in oxidation ponds prior to discharge into a receiving stream.

Prior to 1972, the spent tanning solution had been stored in two 15,000-gallon tanks and sprayed from a tank truck on fields adjacent to the tannery. The current spray field system has been operating since August 1972 and operating procedures are still being worked out.

The alternative to land application would involve chemical and mechanical treatment to adjust the effluent pH and remove the characteristic color and odor prior to discharge into the receiving stream. Water quality standards in the receiving stream include recreational use. Apparently, land application was chosen as the most economical disposal method.

Treatment

The spent tanning solution is pumped into two storage lagoons located adjacent to the spray field. These lagoons are unlined; however, it was reported there was very little liquid lost through infiltration since the solids which settle out of the solution form a coating which acts like a waterproof membrane on the sides and bottoms of the storage lagoons. This coating, as observed on the sides of the lagoons, had an appearance similar to a light prime coat of bituminous material.

The two lagoons have a combined capacity of about 3.5 million gallons. Since daily production is only about 15,000 gallons, there is sufficient storage capacity for the winter months when the spray field is not in use and for a considerable detention time when the spray field is in operation. Other than oxidation and settling in the storage lagoons, no treatment is provided.

Application

A 16-acre tract of pasture land had been purchased in 1971 as an application site. Although no infiltration tests had been performed in connection with this project, it was reported that the Soil Conservation Service had determined that soils in the areas were suitable for septic tank installations.

The spray field portion of the site covers about 10 acres at present and consists of five 4-inch PVC laterals with 1-inch PVC risers and Rainbird sprinkler heads. Spray patterns in the parallel laterals are designed to overlap but overlapping was not taking place since a smaller than design pump motor (5 hp) was being used temporarily.

Severe burning of vegetation was evident in the spray field and the spray pattern was easily distinguished as a series of black circles in the otherwise green field. Although the mature vegetation appeared to be completely dead, new green shoots were observed in the spray areas which were currently being rested. No special planting had been made, although Reed Canary and Kentucky Fescue were being considered as ground cover. At present no treatment was planned to raise the pH and reduce the burning of vegetation.

It was noted that a thin coating of dark-colored material was building up on the vegetation and ground surface in the spray area. This appeared to be the same bituminous-like material that was observed on the sides of the storage lagoons. At present, this coating did not appear to interfere with infiltration; however, it was reported the spray field would be disced or scarified periodically to insure that a waterproof membrane not be formed.

During the inspection only one lateral was in use, while the other four were being rested. No application plan has been developed, other than switching laterals when ponding is observed. When the design pump motor (7-1/2 hp) is installed, an improved spray pattern is expected.

No interceptor ditches or other means of collecting runoff have been developed. Approximately two acres of wooded area serve as a buffer between the spray field and the river. Natural drainage is such that any runoff would drain through this wooded area prior to reaching the river.

The fields which, prior to 1972, had been treated by tank truck as a means of disposing of the spent tanning solution, showed no adverse effects and could not be distinguished from untreated field. It was reported the treated fields had been scarified at least once and that this had greatly improved the ground cover.

The Land Treatment System at Seabrook, New Jersey (1950 - 14 mgd)

Introduction and History

Although data were not gathered for the Seabrook Farms facility in New Jersey, a narrative description is included here. Seabrook farms was a very early industrial user of the treatment process and the description is used because of its many unique features.

The spray irrigation system of Seabrook Farms Company in New Jersey has been in continuous operation since June 1950, receiving an annual application of 1.25 billion gallons of wastewater distributed over 310 gross acres. The wastewater which originates from processing of vegetables ranges in BOD from about 200 mg/l to around 2,000, depending upon the product being processed. (All sanitary wastes are treated separately and the treated water is not mixed with the industrial waste stream.) The quantity of water is also highly variable ranging from a few hundred thousand gallons per day in winter to 16.0 mgd at the height of the packing season.

The problem of stream pollution was recognized during the late 1930's but, due to the wartime shortage of construction materials, little pollution control was attempted - save the construction of some lagoons which by 1946 were totally inadequate. During the next two years, engineering studies led to no feasible means of pollution control which was within the Company's financial capability. Finally, the Company asked Dr. C. Warren Thornthwaite and Associates to join the Company's efforts to investigate the possibility of disposal by irrigation.

Effluent of the quality produced by Seabrook Farms is entirely suitable for crop irrigation and, indeed, had been used for this purpose for many years. However, crop demands for water do not coincide seasonally with the harvest schedule. In fact, during the asparagus season in spring and again in the fall during spinach harvest, excess moisture from rainfall is always a threat and often a problem. Therefore, Thornthwaite's first task was to locate fields within piping distance of the factory which would be in cover crop during high rainfall periods and to discover by trial just how much water these fields could be expected to absorb. It is, perhaps, fortunate that the irrigation experiments at Pennsylvania State University were to come 15 years later. That is, if Seabrook Farms had been constrained by the concept of two inches per week, Thornthwaite would have abandoned the project before it got started, since the 1,800 acres that would be needed to handle 14.0 mgd was simply unavailable.

During periods of drought in the humid east, farmers normally apply 1.0 inch of irrigation water about once a week. Therefore, it was necessary to learn how much more water the land would accept. To achieve this, the company set up a single giant sprinkler in a sandy field with a vigorously growing cover crop of crimson clover. The results were disappointing. After the application of two inches, the soil was waterlogged and became waterlogged again with the application of only a fraction of an inch on successive days. Clearly, something was impeding the movement of water through the soil - probably plow sole which had been formed during 100 years of tillage.

The sprinkler was then moved 200 yards northward into a wooded area which had not been farmed for many years. Investigators were surprised when the area did not flood after eight inches of application. The application was repeated daily for several days with the same result. Finally, after 48 hours of continuous irrigation at the rate of one inch per hour, ponding occurred but the ponds disappeared after a few hours' rest.

During the winter and spring of 1950, the Seabrook system was constructed to occupy wooded areas adjacent to the experimental tract. Initially, there were 72 sprinkler locations, each designed to receive 8 inches per day. Each sprinkler covered a little over an acre and water was applied at approximately 300 gpm. Later, 12 more sprinkler locations were added when some areas did not perform as well as expected.

At the outset, 76 test wells were installed and monitored for groundwater pollution. It soon became evident that the water quality was well within the United States Public Health Standards; NO^3, for example, was never higher than 10 mg/l (2.2 as N). The monitoring program was discontinued after about three years. The test wells also enabled investigators to plot the movement of groundwater and led to the publication of several papers on groundwater hydrology.

For at least eight years and probably longer, the original design concepts were followed, i.e., eight inches per day during periods of stress and lesser quantities where factory production diminished. Meanwhile, a rigorous water economy program reduced the peak flow from 14.0 mgd to about 12.0 mgd.

The Physical Setup

The soils of the Seabrook treatment site lie within the sassafras soil formation and are generally sandy in character. However, within the spray area the silt and clay content is extremely low, resulting in a very low water retention capacity. Therefore, the land has low agricultural value and for this reason was abandoned to forest many years ago.

In 1950, the trees were largely oaks, with a few cedars, ironwood, gum and dogwood scattered among them. The growth was sparse and scrawny, with large trees only in the low areas where water was available. Clearly, this vegetation was thoroughly acclimated to the poor soil and was able to survive long periods of severe drought. It just barely missed becoming a grassland area similar to the Quinipiac Valley in Connecticut where glacial outwash deposited several feet of sterile land. It was obvious from the outset that these deep-rooted upland oaks could not survive the application of large quantities of water which drowned the zone of aeration. Surprisingly, however, the trees have survived in areas immediately adjacent to the sprinkler circle, indicating very little lateral movement of water near the soil surface.

Nothing has ever been done at Seabrook to alter the natural ecological succession, and observations over the years indicate that the flora and fauna have now stabilized in their new environment. During the first few years while the trees were dying, a weed known as Lambs Quarters grew to gigantic proportions. Gradually, this growth was replaced by Smart Weed, Chick Weed, Blackberries, Wild Currant and Wild Roses. The dominant species now is marsh grass of a variety which grows to a height of 10 feet or more in the lowlands of New Jersey - very decidedly a foreigner to these upland soils of the spray area. It is also noted that the vegetative litter on the soil surface has ceased to accumulate, indicating that the rate of production is now matched by the rate of degradation.

The water for the Seabrook factory is pumped from 14 deep (150-foot) wells, all located within an area of less than one-half section. After being discharged from the factory, the wastewater flows by gravity to a screening station where small pieces of vegetable are removed on vibrating screens. From there, the water flows to a lift station and thence into a canal which conveys it 1.7 miles to the disposal site. The capacity of the canal is 3.0 mg and provides the treatment system with adequate surge capacity. Located along the canal are two major pumping stations which remove water during the summer for the irrigation of vegetable crops. (Since there is zero input of pathogens or residue of an animal nature, there is no constraint upon the use of this water for this purpose.) Downstream from the field, irrigation pumping stations are seven 100 hp pumps which supply the treatment area. These discharge into 8-inch steel force mains which, in turn, break down to 4-inch laterals to supply each nozzle.

Hydrological studies during the early 1950's showed that the water applied to the treatment area flowed underground in a general southwesterly direction and probably emerged as springs and seeps in the watershed of the Cohansey River. Because of this southwesterly flow, it is highly unlikely that any of the treated water finds its way northeasterly to the well field which supplies the factory. Therefore, the only reuse which can be claimed is the relatively small quantity withdrawn from the canal for crop irrigation.

Winter Operation

During the early 1950's, there was a complete shutdown of the factory during winter, and the treatment area received no water. Around 1953, the winter processing of potatoes made it necessary to operate the system during weather which occasionally dropped to below zero. At first, there was apprehension that the surface piping could not survive under these extreme conditions and that wastewater would flow into the streams over the frozen soil if there was a sudden thaw.

The problem was solved by disconnecting all but three sprinklers on each operating line and operating these continuously as long as the weather remained cold. This technique caused the formation of huge blocks of ice within the sprinkler pattern. When warm weather returned, the ice melted slowly from the bottom up and gradually percolated into the soil. No overland runoff has been experienced. It should be pointed out that Gerber Products Company in Fremont, Michigan, has had similar experience, but the technique will not be successful where moving equipment is used, such as that being installed at Muskegon, Michigan. In that instance, winter storage is essential.

The Situation in 1973

Aside from the continuing high performance which many predicted would be exhausted by now, the most significant change in the system has been an alteration of the soil structure. One can only speculate as to what has happened, but it is very evident the soil has become even more permeable than it was in 1950.

As mentioned above, standard operation initially called for the application of eight inches per day at the rate of 1.0 inch per hour during peak flow periods. Careful scheduling was maintained during periods of less than peak flow so that each area was given opportunity to rest and recover in order to be ready to accept the next increment of heavy flow. In 1973, the operating time has been extended to 12 hours per day, and of even greater importance, no attempt is made to evenly distribute the flow throughout the tract. That is, when production falls off, the areas most distant from the control house are not used and the nearby sprinklers continue to receive the 12-inch application. Thus, in theory, a single sprinkler might receive as much as 350 acre-feet per year, which closely approaches the loading rate of the percolation beds at Flushing Meadows, Arizona. Quite obviously, this change in operation has brought about a substantial saving in labor.

The piping and sprinkler arrangement has not been significantly altered in 20 years and there has been no attempt to automate the controls. In fact, the labor cost of operation is so low that auto controls would only be a convenience and could not be justified by a saving in labor.

The annual operating cost is to the order of $60,000 which amounts to 4.8 cents per 1,000 gallons. It should be pointed out, however, that because of the seasonal nature of the Seabrook operation, the flow from the factory on a year-round basis is only 30 percent of the designed capacity of the treatment system. That is, if the flow were a uniform 10 or 12 mgd, the cost of treatment would be significantly less.

Three or four years ago, some local residents were informed that Seabrook was responsible for the eutrophication of a downstream lake. There was suspicion that the phosphorous absorption capacity of the Seabrook treatment system had been finally exhausted. Accordingly, 10 new test wells were installed and samples collected. Although the specific results of sample analysis are not available, the Company has reported that the phosphorous removal is nearly complete and there has been no change in the groundwater quality since the sampling program of 20 years ago. The record of a similar experience has been published by the United States Water Conservation Laboratory in Phoenix, Arizona, and confirmed in a personal interview with Dr. Hermann Bouwer.

Conclusion

The wastes treatment system of Seabrook Farms Company, after 23 years of operation continues to achieve a very high degree of water purification. Quite contrary to early predictions, the system has lost none of its treatment efficiency and has, in fact, improved. The original vegetation within the sprinkler pattern has been replaced by species which are ideally adapted to the environment.

APPENDIX C
ON-SITE SURVEYS OF LAND APPLICATION FACILITIES

Data from completed on-site field investigations collected by use of the questionnaire, Appendix A, has been tabulated for reference purposes.

Facilities which were found to use wastewater for only their treatment plant grounds, which had abandoned the use of land application, or which use evaporation-percolation systems are not included.

Although data from Mexico City (items 66, 67) was collected and reported herein, the data were not included in the tabulations contained within the report.

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DATA

LAND APPLICATION FACILITIES

A Municipal

Ref. No.	Agency & State	Pop. Served	Pop. Equiv. of Waste	Community Data Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other
1	City of Casa Grande, Arizona	12,500	13,700	c
2	Lake Havasu San. District Lake Havasu, Arizona	4,000	4,000	c,f
3	City of Mesa, Arizona	47,000	53,000	c
4	City of Prescott, Arizona	13,000	13,000	c,e
5	City of Tucson, Arizona	283,000	475,587	c,f
6	City of Bakersfield (Plants 1 and 2) California	101,700		c
7	Mt. Vernon County San. Dist. Bakersfield, California	28,500		c
8	Las Virgenes Municipal Water Dist. Calabasas, Los Angeles, California	20,000	20,000	c,f
9	Camarillo San. Dist. Camarillo, California	22,000	24,000	c
10	City of Colton, California	20,000	30,500	c,f
11	City of Dinuba, California	8,100	18,000	c,e
12	City of Fontana, California	21,000	21,000	b
13	City of Fresno, California	170,000	795,431	c,e
14	City of Hanford, California	16,000	18,000±	c,e
15	Valley Sanitation Dist., California	22,000	35,000	b,e,g
16	Rossmoor Sanitation, Inc. Laguna Hills, California	28,000	28,000	c,f
17	City of Livermore, California	48,000	49,000	c,f
18	City of Lodi, California	29,950	30,000	c,e,f
19	Irvine Ranch Water Dist. Irvine, Orange, California	22,800	22,800	c,f,g
20	City of Oceanside, California	47,000	47,000	c,e,f
21	City of Ontario, Ontario, San Bernardino, California	100,000		c,e
22	City of Pleasanton Sewage Treatment Plant Pleasanton, Alameda, California	17,000	17,000	c,e
23	City of Santa Maria Wastewater Treatment Plant, Santa Maria, Santa Barbara, California	34,000		c,e

DATA
LAND APPLICATION FACILITIES

Community Data

	Sludge Disposal					
Ref. No.	Treatment a) Thickening b) Digesting c) Filtering d) Drying Beds e) Other	Disposal a) Irrigation b) Tank Truck c) Spreading d) Other	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Combined Sewer System % of (Yes) (No) System	Is Storm Water Treated (Yes) (No)
1	d	c	2.0	3.0	N	N
2			.6	.6	N	N
3			4.3	5.0	N	N
4	d		1.5	1.8	N	N
5			28.1	36.9	N	N
6	b	c	11.3	31.0	N	N
7	b	b	3.6	6.5	N	N
8			3.0	7.5	N	N
9			2.3	4.8	N	N
10	d	d	1.9	2.4	N	N
11	b,d	c	2.4	1.0	N	N
12			2.3	2.5	N	N
13	b,d	c	50.0	106.0	Y	Y
14	b,d	c	2.5	6.5	N	N
15			3.3	5.0	N	N
16			1.4	2.2	N	N
17	b	c	4.0	5.0	N	N
18	b	c	3.7	3.5	N	N
19			2.8	5.0	N	N
20			5.0	5.0	N	N
21			11.0	16.0	N	N
22	b	b	1.3	1.7	N	N
23			4.8	6.5	N	N

DATA
LAND APPLICATION FACILITIES

		Wastes to Disposal by	Total Area (acres)					
Ref. No.	Year Start	a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused
1	1958	d	34.8	34.8				
2	1971 (golf course)	c	80.0	80.0				
	1967 (plant grounds)							
3	1957	a	274.0	95.0		4		175^+
4	1960-62	c	65-70	65-70				
5	1917	a,b,c	$2800^{\pm}$	$2450^{\pm}$		$50^{\pm}$		$300^{\pm}$
6	1930's	a	2400	2400				
7	1948	c	1000	650				350
8		b,c	420	420				
9	1958	a,c	400	394				
10	1954	a,b	113	111	1-2			
11	1954	b	99	60		2	10	27
12	1971-72	b,c	112	112				
13	1891	a	1800	1200^+		300	20±	
14	1900's	a	265	155		85	25	
15	1928	b,c	198	198				
16	1964	b,c	1420	1420				
17	1965	b,c		440				20
18	1944	b,c	434	339		60	35	
19	1968	b		500				
20	1957	a,c	330	290		40		
21	1915	c	160	140		20		
22	1957	c	175	155	c	1	6	20
23	1935	a,c	155	155				

DATA
LAND APPLICATION FACILITIES

Ref. No.	Months Used	Average Flow (mgd)	lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Ground Cover (acres) and Annual Return					
					Grass		Forest		Not Culti-vated	No Vege-tation
					Acre	Return	Acre	Return		
1	12	2.0		c,d,e						
2	12	0.6		d,e	80					
3	12	4.3		d,e	55					
4	9-10	0.1			65-70					
5	12	14.0		a,d						
6	12	11.3		a,c	785					
7	12	3.6	1,090	c	390				350	
8	12	3.0		a	20	$15/ac-ft			varies	
9	12	2.3		a						
10	12	1.9		a,d	62				34	
11	12	2.4	800	b,d					46	
12	12	2.3		d,e	3					
13	12	50.0	62,950	c,d,f	25					
14	12	2.5	400	a,d						
15	7	2-4		a,d						
16	12	1.4		b,c,d	420					
17	12			a,c,e	100					
18	12	3.7-5		a,d	339					
19	12	2.8		d	Yes					
20	12	1.5		d					40	
21	12	0.9		b,d	140					
22	12	1.3	217	a	155					
23	8	4.8		d	115					

DATA
LAND APPLICATION FACILITIES

Ref. No.	Crop	Acre	Return	No. of Days/ Week Irri- gated	Application Rates							
					in./hr.		in./day		in./wk.		in./yr.	
					Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
1	Cotton & Alfalfa	34.8										
2				7			0.6	0.6				
3	Sorghum	40		7								
4				7								
5	Cotton	2,450	$31,000 most at $1/ac-ft	7								
	Milo											
	Maize											
	Alfalfa											
6	Barley	600										
	Corn	690										
	Cotton	500										
	Alfalfa	175		variable				0.2		1.2		62
7	Barley	130										
	Alfalfa	130		7				0.2		1.4		75
8	Alfalfa	400		7								
9												
10	Oats & Corn	15										
11				7				1.5				
12	Citrus	72										
	Hay	17										
	Grapes	20										
13	Pasture	1,000		7								
14	Corn	155	$3,500	7								84
	Oats											
	Cotton											
15	Cotton	150		3-5								
16		1,000		7								
17	Alfalfa	290		7								
	Row Crops											
18			$8,475	7								
19	Citrus											
	Vegetables											
20	Alfalfa	250		3-4,7								
	Fodder											
	Corn											
	Pasture											
21			$6,000	7								
22			$12,900	7	0.02	0.01	0.4	0.3	2.8	2.2	147.4	112.9
23	Alfalfa	40		7								

DATA
LAND APPLICATION FACILITIES

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press) c) Tilling d) Overland Flow e) Ridge & Furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre	Year Purchased	Annual Cost Lease ($)	Term Lease (Year)	Value/land 1972 Est. ($/acre) Facility	Value/land 1972 Est. ($/acre) Adj. Land
1	d,e	N					600	600
2	a	N						
3	d	N	1,425	1959	21	13	3,000	4,000
4	a	N		1957				
5	d	N				20		
6	d	Y				8	1,000	1,500
7	f	N				8	1,000	1,500
8	a	N	4,500	1965			7,000	7,000
9								
10	d	N					5,000	5,000
11	e	N	1,500	1954-1957			2,000	2,000
12	e	N					4,000	4,000
13	f	N	0-1,000±	1891 to present			1,000 2,000	1,000 2,000
14	f	N	875	1900 to present			875-900	900
15	a,e,f,	N	200-3,000	1940-1967	20	1	5,000	10-17,000
16	a,e,f	N						
17	b,f	N	5,500	1965			7,500	7,500
18	f	N	to 1,000	1944 1965 1968			1,000	1,000
19	a,c	N	0	1800				20,000
20	a	N				40	4,200	4,200
21	a	N		1915-1958	20,000	25	12,000	12,000
22	b	N			12,900	2	2,000^{+}	2,000^{+}
23	a	N	58	1913	600	5	5,000	5,000

DATA
LAND APPLICATION FACILITIES

Land Application Facilities					Operation and Maintenance			
	Capital Improvements					Holding Ponds		
Ref. No.	Cost $	Year Made	Cost (mgd) $	Distance to Nearest Residence (Miles)	Annual Budget $	cap. (mgd)	area (acre)	Treatment at Site a) Aeration b) Chlorination c) Other
1		1958		0.5		12.0	12.0	
2	1000/acre	1967		Adj.		1.5	2.0	b
3				0.25		4.0	4.0	
4		1957		Adj.				
5				0.01		20.0	50.0	
6				1.0				
7	361,400	1966	99,000					
8	700,000	1972		Adj.	30,000	45.0	8.0	
9						150.0	6.0	b
10				Adj.				
11	11,000	1972	4,600	0.06		2.0	2.0	a,b,c
12	16,000	1971	16,000	Adj.		1.0	1.5	
13				0.1		684.0	300.0	
14	50,000±	1954 1955	20,000	0.25		113.0	85.0	
15				0.02		18.0	12.0	N
16	300-700/ acre			0.25		13.0	3.5	
17	245,000	1965	49,000	0.5				a,b
18	60,000	Many Years		2		130.0	60.0	a,b
19				Adj.		309.0	47.0	
20				0.04	63,700	75.0	40.0	
21		Early 1960's		0.02				b
22	5,000	1971	3,600	0.2	35,000	5.0	6.0	a
23	10,000	1971	2,000	0.25		48.0	36.0	N

DATA
LAND APPLICATION FACILITIES

	Land Used For						
Ref. No.	Farm	Graze	Other	Security Used a) Fenced b) Accessable to Public c) Patrolled d) Posted e) Other	Residence On Premises	Recreation Use-Site	Public Health Restrict (Yes) (No)
1	x	x		b	N	N	N
2				a	Y	Y-Golf	N
3	x	x		a	Y	N	Y
4					N	Y-Golf	N
5	x	x		a	Y	N	Y
6	x			b	N	N	Y
7	x	x		b	N	N	N
8	x	x		a,b,c,d	Y	Y-Fishing	Y
9	x		x	d	Y	N	Y
10	x	x		a	N	N	Y
11				a,d	N	N	N
12	x			b,d	Y	N	Y
13	x	x		a,c,d	Y	N	Y
14	x	x		a,b,d	N	N	Y
15	x	x		a	Y	N	Y
16	x	x	x	a,c,d	N	Y-Golf	Y
17		x		b	N	Y-Golf	Y
18		x		a,c,d	Y	N	Y
19	x	x		b,c,d	Y	N	Y
20	x	x		a,c,d	Y	N	Y
21			x	b,c	N	Y-Golf	Y
22		x		a,c,d	N	N	Y
23	x	x		a,d	N	N	Y

DATA
LAND APPLICATION FACILITIES

System Performance

	Test Wells		Monitoring Program		Effluent		Effluent		
Ref. No.	No.	Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Re-used	Re-apply	Dis-charge to Receiv-ing Water	Lost to Ground Water	Ground Water Inteferes with Operation (Yes) (No)
1	N							x	N
2			b	d				x	N
3								x	N
4								x	N
5	0			d			x		N
6	2	15-30	b,e			x		x	Y
7	1	30	b,e			x		x	Y
8			b					x	N
9			b	d			x	x	N
10			a,b,f					x	N
11	1	90	b,c,d					x	N
12			e					x	N
13	20	100-300	b,d,f	d,w				x	N
14	1	250	a,b,d	o,w				x	N
15	0		b,f	d				x	N
16			a,d,f	d,o				x	N
17	0		a,c,e	d,y			x	x	N
18	0		b	d			x	x	N
19	0							x	N
20	5	100	a	d				x	Y
21			a	d				x	N
22	4	50	b,c,d,e,f,g	d,d,y,o,y,y				x	N
23	0		b	d				x	N

DATA
LAND APPLICATION FACILITIES
System Performance

a) Buildup/N
b) Buildup/Heavy Metal
c) Buildup/Chlorides
d) Effect/Plants
e) Effect/Animals
f) Deterioration Groundwater Quality
g) Deterioration Receiving Water Quality
h) Effect/Water Table
i) Odors
j) Health Hazards
k) Other

Ref. No.	Data Available On	Future Plans				Information on Parameters Available					
						BOD mg/l		SS mg/l		COD mg/l	
		Expand	Continue As Is	Decrease	Abandon	To Land	Groundwater	To Land	Groundwater	To Land	Ground Water
1		x									
2	a,b,c,d,i,j	x				10		0		1.3	
3		x				50		30		7.6	
4			x								
5	f,h	x				65		19			
6	h		x								
7	f,h		x								
8	d,e,f,i,j,g	x				5		2		24	
9		x				8-15		2-16			
10	b,d,f,g,h		x			20		6		0	
11			x								
12			x			95-115		25-30			
13	c,f,h,i	x				251		151		547	
14	h,i	x				Y		Y		Y	
15		x				12		47			
16		x				2-10		5-20			
17	c,d,e,f,g,h,i,j	x									
18	g	x				Y		Y			
19	f,g	x				10-15		10-20		0-40	
20	f,g,h,i,j	x				45		16			
21		x				40		50			
22					x	Y		Y		Y	
23	f,g,h,j		x			35		40			

DATA
LAND APPLICATION FACILITIES
System Performance
Information on Parameters Available

Ref.	pH		Fecal Coli/100ml		P mg/l		Total N mg/l		Nitrate mg/l				Cl mg/l	
No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water
1														
2	7.2								0					
3	7.6													
4	7.1													
5														
6														
7														
8	7.3		2		33		3		10		0.14		106	
9	7.5-7.8		2-10										188	
10	7.2												65	
11														
12	7.1												50	
13	7												67	
14														
15	7-8		23/100											
16	7.0-7.5		2.2		18-24		1-10		3-15				180-195	
17														
18														
19	7.5-7.6				10-16		5-15		1-8		0		150-170	
20	8.2				20		7.5		0.56				300	
21	7.4								4					
22														
23	7.7-8.0								21				280	

DATA
LAND APPLICATION FACILITIES

Ref. No.	Operated by Agency? (Yes) (No)	Descriptive Evaluation			Depth to Groundwater Table (ft)	Average Slope Application Area (%)	Climate Class (APWA)
			True Land Disposal				
		Supplemental Irrigation	As Irrigation	As Treatment Facility			
1	N			x	60	2	B
2	Y			x	30	<2	B
3	Y			x	30-50	0.2	B
4	Y	x			250	2	B
5	N	x			100-120	<2	B
6	N		x				A
7	N		x				A
8	Y, N			x	10	0-5	A
9	N		x		36	2	A
10	N	x			50-80	<2	A
11	Y			x		<2	A
12	N			x	100-125	2	A
13	Y		x				A
14	N			x		<2	A
15	N	x			13	<1	A
16	Y			x	15	0-30	A
17	N	x					A
18	N	x			3-4	<1	A
19	Y			x	20-25	<2	A
20	N		x		0-40	5	A
21	N	x			150	2	A
22	N			x		<2	A
23	N		x		100-150	1	A

DATA
LAND APPLICATION FACILITIES

A Municipal

Ref. No.	Agency & State	Pop. Served	Pop. Equiv. of Waste	Community Data Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other
24	City of San Bernardino, California	140,000	140,000	c,f
25	Santee County Water Dist. San Diego, California	30,000	30,000	c,e,f
26	City of San Clemente, California	20,000	20,000	c,f,g
27	Golden Gate Park Water Reclamation Plant, San Francisco, California	10,000	10,000	c,f
28	City of San Luis Obispo, California	42,000	42,000	c,e,f
29	City of Ventura, California	40,000	42,000	c,e,f
30	City of Woodland, California	23,000	132,500	e
31	City of Colorado Springs, Colorado	198,000	240,000	d,f
32	Walt Disney World, Florida	50,000	50,000	d
33	Okaloosa County Water & Sewer Dist., Eglin Air Force Base, Florida	15,000		c,f,
34	City of St. Petersburg, Florida	51,000	51,000	c,f
35	City of Tallahassee, Florida	15,000		c,f
36	St. Charles Utilities, Inc. St. Charles, Maryland	6,000	6,000	e
37	Forsgate Sanitation, Inc. Cranbury, New Jersey	4,000	4,000	d,e,f
38	City of Vineland, New Jersey	8,000		b,g
39	City of Alamogordo, New Mexico	25,000		c
40	City of Clovis, New Mexico	28,000	75,000	b,e
41	City of Raton, New Mexico	2,300		b,f
42	City of Roswell, New Mexico	40,000		c
43	City of Santa Fe, Siler Road Plant, New Mexico	20,000		c
44	City of Santa Fe, Airport Road Plant, New Mexico	25,000		c
45	Clark County, Nevada			c,f
46	City of Ely, Nevada	6,000		c,e

LAND
LAND APPLICATION FACILITIES

Community Data

Ref. No.	Sludge Disposal		Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Combined Sewer System (Yes) (No) % of System	Is Storm Water Treated (Yes) (No)
	Treatment a) Thickening b) Digesting c) Filtering d) Drying Beds e) Other	Disposal a) Irrigation b) Tank Truck c) Spreading d) Other				
24		d	15.0	28.0	N	N
25			3.2	4.0	N	N
26			2.2	4.0	N	N
27		d	1.0	1.0	Y 100	N
28	d	d	3.2	5.0	N	N
29			3.4	4.0	N	N
30			8.7	15.0	N	N
31	a,b,d	c	25.0	18.0	N	N
32			1.5	10.0	N	N
33	b,e	d	1.0	3.0	N	N
34			5.0	9.0	N	N
35	b	d	2.1	2.5	N	N
36	None	d	.5	.7	N	N
37	a,b,c	c	.4	3.0	N	N
38		d	1.2	4.0	N	N
39	d	d	2.5	2.2	N	N
40			3.5		N	N
41	d	d	0.5	.9	N	N
42	d	d	2-3	6-7	N	N
43	d	c	2.5	3.0	N	N
44	d	c	2.8	3.0	N	N
45			13.0	12.0	N	N
46	b	c	1.5	3.0	N	N

DATA
LAND APPLICATION FACILITIES

Ref. No.	Year Start	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Total Area (acres)					
			Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused
24	1962-1963	c	70	70				
25	1959	a	170	115				55
26	1957-1968	b,c,d	200	200				
27	1932	c	1000	800		1.2		200
28	Prior 1948	a,c	52	52				
29	1965	c	275	175-200				100-75
30	1889	a	1400	240		120	400	640
31	1953	c	915	755				160
32	1972	c	100	100				
33	1972	c	80	24	2	4		50
34	1972	c	4	4				
35	1966	c	36	36				
36	1966	c	100	50	30		20	
37	1967	c	612	300		66	5.7	300
38	1901	b	167	30			2	135
39	1963	a	260	260				
40	1927	b	1193	1152		40		
41	1950	a,b	200	200				
42	1930's	b,c	770	760		10		
43	1937	b	640	640				
44	1962	c	100	98		2		
45	1961	c						
46	1908	a	2064	1400	600	8	11	45

DATA
LAND APPLICATION FACILITIES

Ref. No.	Months Used	Average Flow (mgd)	lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Ground Cover (acres) and Annual Return					
					Grass		Forest		Not Culti-vated	No Vege-tation
					Acre	Return	Acre	Return		
24	12	1.0		d	70	$5/ac-ft (golf)				
25	12	1.0		a,c,d	110		5			
26	12	0.3		b,c,e	200					
27	7	1.0	100	d	600		200			
28	6			c	52	$3,432				
29	12	1-2	25	d	175-200					
30	6	8.7		a,b,c					750	
31	6	4-7		c	755	$36,600				
32	12	1.5		d	46					
33	12	1.0		d			24			
34	12	0.2		d	4					
35		2.0		d			20			
36	12	0.5	210	d			50			
37	6	0.4		d	300					
38	12	1.2		d					30	
39	12	2.5		a,b,c						
40	12	3.5		a,d						
41	7			a,b						
42	12	2.3		a,e	260					
43	7	2.5		a,d						
44	9	0.8		a,d	98					
45				e						
46	7	1.5		a,d						

DATA
LAND APPLICATION FACILITIES

Ref. No.	Crop	Acre	Return	No. of Days/ Week Irri- gated	Application Rates							
					in./hr.		in./day		in./wk.		in./yr.	
					Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.
24				7								
25				7								
26				5,7								
27				1					1.5	1.0		
28				5								
29				7								
30				1					1.5	1.5	30.0	30.0
31				7								
32				7	1.00				2.5	2.0		
33				7	0.20	0.20	1.6	1.6	11.2	11.2	582.0	582.0
34					0.37		8.9		62.0			
35	Corn, Millet, Kenaff, Bahia Grass, Sudan Grass, Sorghum		$0	7	1.00	1.00	8.0	2.0	8.0	4.0		
36				6	0.25	0.13	1.0	0.5	2.0	1.0	100.0	52.0
37												
38				1-2	1.00	0.5-1	12-18	12.0	12-18	12.0	25.0	20.0
39	Alfalfa											
	Corn, Oats											
	Sorghum	260	$1,400	7								
40	Milo	750										
	Alfalfa	400	$750									
	Corn, Millet Wheat											
41	Alfalfa	200	$250									
42	Alfalfa	350	$3,200									
	Barley	160										
	Corn											
	Cotton											
43	Alfalfa		$200									
	Apples		$250									
44												
45												
46	Alfalfa	300	$4,200	7							4-96	4-48
	Hay	1,100										

DATA
LAND APPLICATION FACILITIES

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press.) c) Tilling d) Overland Flow e) Ridge & Furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre	Year Purchased	Annual Cost Lease ($)	Term Lease (Year)	Value/Land 1972 Est. ($/acre)	
							Facility	Adj. Land
24	a	N		1963				
25	a	N	230	1956				30,000
26	a	N	0	1929				20,000
27	b	N	800	1868				
28	e	Y	5,000	1933-1960		5	8,000	
29	a	N	0					
30	f	Y	100-	1964			800	
31	a	N						
32	b	N						
33	a	N			1	10		
34	a	N						
35	a,b	N	400	1965			1,500	2,000
36	a	N	1,000	1966			2,500	2,500
37	a	N	1500	1964			10,000	6,000
38	f	N		1928-1970			500-1,000	500-1,000
39	f	N					650	650
40	e	N					450	450
41	f	N					800	800
42	a,f	N					1,000	20
43	f	N					3,000	3,000
44	a	N					3,000	3,000
45								
46	f	N	75	1946			300	100

DATA
LAND APPLICATION FACILITIES

	Land Application Facilities				Operation and Maintenance			
	Capital Improvements					Holding Ponds		
Ref. No.	Cost $	Year Made	Cost (mgd) $	Distance to Nearest Residence (Miles)	Annual Budget $	cap. (mgd)	area (acre)	Treatment at Site a) Aeration b) Chlorination c) Other
24		1963		0.02				b,c
25				Adj.	24,000	22.0	2.4	N
26				Adj.	35,800	2.9	0.5	b
27		1967		0.02		2.0	1.2	a,b
28				0.01		8.0	6.0	
29				Adj.				N
30	90,000	1970				540.0	520.0	
31	1,312,980	1953-1971		Adj.	137,689	5.5		b
32	100,000	1972		2				None
33	460,000	1972	153,000	1		6.0	4.0	None
34				0.04				b
35	35,000	1966-1972	8,750	0.5				b
36	95,000	1966-1971	190,000	0.5	12,000-15,000	12.0	20.0	a,c
37				0.6		28.0	12.3	b,c
38				0.33				
39		1963		Adj.				
40				Adj.			40.0	
41	200	1950		0.2				
42	Unknown	1964		On-site		15.0	10.0	
43		1937-1952		Adj.		0		
44		1962		0.04		3.0	2.0	
45								
46	5,000	1967	3,333	0.25	22,000	9.5	7.25	a,b

DATA
LAND APPLICATION FACILITIES

Ref. No.	Land Used For			Security Used a) Fenced b) Accessable to Public c) Patrolled d) Posted e) Other	Residence On Premises	Recreation Use-Site	Public Health Restrict (Yes) (No)
	Farm	Graze	Other				
24			x	a,b	N	Y-Golf	N
25	x		x	a,d	N	Y-Golf	Y
26			x	b,c	N	Y-Golf	N
27				b		Y-picnics, riding, hiking	Y
28		x		a		N	Y
29			x	b,d	N	Y-Golf	Y
30	x		x	a,c,d		Y-Hunting	Y
31				b	Y	Y-Golf	Y
32	N			a	N	N	N
33	N			a	N	N	N
34	x			a	N	N	N
35	x			a	N	N	N
36					N	N	N
37				b	Y	Y-Golf	N
38				a	N	N	N
39	x			b	Y	N	N
40		x		b	Y	N	N
41	x	x		a	Y	N	N
42	x	x	x	b	Y	Y	N
43	x	x		b	Y	N	N
44				b	N	Y-Golf	N
45					N	Y	N
46	x	x		a,d	Y	N	Y

DATA
LAND APPLICATION FACILITIES

			System Performance						
			Monitoring Program				Effluent		
	Test Wells				Effluent				
Ref. No.	No.	Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Re-used	Re-apply	Dis-Discharge to Receiving Water	to Ground Water	Ground Ground Water Inteferes with Operation (Yes) (No)
24									
25	0	a	w					x	N
26	1		a,b,d,f	d,d,o				x	Y
27	0		b,c					x	N
28			b,c	w				x	N
29			b,c	d				x	N
30								x	N
31	0						x	x	N
32	1		d,e,f					x	N
33	4	32	c,e	w				x	N
34	11	varied	d,e	d,o				x	N
35	8	40-300	d,e,f	w,o				x	
36	0		c	monthly				x	N
37	1		b,c,e	d,d,bi-monthly				x	Y
38								x	N
39								x	Y
40								x	N
41								x	N
42								x	N
43	0							x	N
44	0							x	N
45							x		N
46	0		b,c	monthly			x	x x	N

System Performance

a) Buildup/N
b) Buildup/Heavy Metal
c) Buildup/Chlorides
d) Effect/Plants
e) Effect/Animals
f) Deterioration Groundwater Quality
g) Deterioration Receiving Water Quality
h) Effect/Water Table
i) Odors
j) Health Hazards
k) Other

Ref. No.	Data Available On	Future Plans				Information on Parameters Available					
		Expand	Continue As Is	Decrease	Abandon	BOD mg/l To Land	BOD mg/l Groundwater	SS mg/l To Land	SS mg/l Groundwater	COD mg/l To Land	COD mg/l Ground Water
24		x	x			5-10		30-35			
25			x			18		25			
26	a,b,c,d,e,f,g,h,i,j,k	x				9		5			
27	j		x			5-10		5-15			
28	g		x			17		10			
29		x						25			
30			x			42		88			
31	d	x									
32			x								
33			x			15					
34			x			4.8					
35	a,c,f	x									
36		x									
37		x				5					
38											
39		x									
40	i		x								
41	i	x									
42			x								
43		x									
44											
45			x								
46			x								

DATA
LAND APPLICATION FACILITIES

System Performance

Information on Parameters Available

Ref.	pH		Fecal Coli/100 ml		P mg/l		Total N mg/l		Nitrate mg/l				Cl mg/l	
No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water
24	7.3- 7.9								0-15				64-67	
25					19				22				240	
26					50				25					
27			22		1-10		40-60		0-15		0-1			
28	7.2				33				76		170			
29	7.1		2.2										700	
30	9.8		14.6x 104		7.9		10.6		0.1					
31														
32														
33														
34	7.3		600		5.8		12							
35	6.5-7		10		1		10						50	
36														
37	6-7	6-7												
38														
39														
40														
41														
42														
43														
44														
45														
46														

DATA

LAND APPLICATION FACILITIES

Descriptive Evaluation

Ref. No.	Operated by Agency? (Yes) (No)	Supple-mental Irrigation	As Irrigation	As Treatment Facility	Depth to Groundwater Table (ft)	Average Slope Application Area (%)	Climate Class (APWA)
24		x			20-30	<2	A
25		x			4-5	<2	A
26		x			10-160		A
27		x					A
28		x			12	2	A
29		x			6-8	2	A
30		x					A
31		x			30+	0-10	D
32				x	10-20	<2	C
33				x	40	<2	C
34				x	5	<1	C
35				x	40	<1	C
36	Y			x	4-6	<2	C
37	Y			x			D
38	Y			x	0-4	<2	D
39	N		x		20	<2	B
40	N		x		240	<6	B
41	N	x			5	<2	B
42	N		x		15	2-6	B
43	N		x		200	<2	B
44			x		200	2-6	B
45	N						
46	N		x		2-6	<2	B

DATA
LAND APPLICATION FACILITIES

A Municipal

Ref. No.	Agency & State	Pop. Served	Pop. Equiv. of Waste	Community Data Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other
47	Incline Village, Nevada	4,000	2,400	c,f
48	City of Las Vegas, Nevada	190,000		c,f
49	City of Duncan, Oklahoma	20,000		c,e
50	Unified Sewerage Agency Forest Grove, Oregon	8,000	23,250	b,e,f
51	City of Hillsboro, Oregon	6,000	12,910	c,f
52	City of Milton-Freewater, Oregon	4,150	28,500	c,f,g
53	Pennsylvania State University, State College-University Park, Pennsylvania	37,000	37,000	c
54	City of Dumas, Texas	9,770	13,000	c
55	City of Kingsville, Texas	30,000	26,300	b
56	City of LaMesa, Texas	11,400	11,000	b,e,f
57	City of Midland, Texas	62,000	62,000	b,e
58	City of Monohans, Texas	8,000	8.000	b
59	City of San Angelo, Texas	64,000	73,600	b
60	City of Uvalde, Texas	9,000	12,250	b,e
61	City of Ephrata, Washington	5,255		b,e,f
62	Town of Quincy, Washington	3,200		b,e
63	City of Wala-Wala, Washington	25,000	343,000	
64	City of Cheyenne, Wyoming	42,000		c
65	City of Rawlins, Wyoming	10,000		a
66	Mexico City D.F. – treated	1,600,000		c
67	Mexico City D.F. – raw	6,400,000		a
68	Moulton-Niguel Water Dist., California	5,000		c,d,f
69	City of Abilene, Texas	100,000		c,e,f

DATA
LAND APPLICATION FACILITIES

Community Data

	Sludge Disposal					
Ref. No.	Treatment a) Thickening b) Digesting c) Filtering d) Drying Beds e) Other	Disposal a) Irrigation b) Tank Truck c) Spreading d) Other	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Combined Sewer System % of (Yes) (No) System	Is Storm Water Treated (Yes) (No)
47	b	c	.5	3.5	N	N
48	b	d	26.9	30.0	N	N
49	d	d	2.5	5.2	N	N
50	b	b,c	1.6	10.0	N	Y
51	a,b	b,c	1.0	15.0	Y	Y
52	b	c,d	2.0	9.0	N	N
53	b	b,c	3.7		N	N
54	d	d	1.0	3.0	N	N
55			3.0	.5	N	N
56	d	d	.6		N	N
57	d	c,d	4.3	6.0	N	N
58	d	c	.8	3.0	N	N
59		d	5.0	5.0	N	N
60	d	c	.9	1.0	N	N
61	b,d	c	.5	1.5	N	N
62	b,d	b,c	.8	.5	N	N
63						
64	b		7-7.5	8.0	N	N
65			3.0		N	N
66	None		64.0	96.0	Y 100%	N
67	None		256.0	2560.0	Y 100%	Y
68	b	c	.5	.8	N	N
69	b,d	c	9.0	20.0	N	N

DATA
LAND APPLICATION FACILITIES

Ref. No.	Year Start	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Total Area (acres)					
			Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused
47	1971	b,c	200	200				
48	1959	c	780	780				
49	1964-1965	a	180	180				
50	1951	c	40	40				
51	1939	b,c	413	165	120	3	.25	
52	1946	b,c	1018	1000		18		
53	1963	c	80	60	Several Hundred			Several Hundred
54	1962	b	585	180		5		400
55	1952	c	606	600		5-6		
56	1960	b,c	192	190		2		
57	1950	a	1000	600		300		100
58	1945	b	40	38		2		
59	1933	b	740	640		60	40	
60	1938	a,c,f	150	130		20		
61	1972	c	120	55		12	4.5	48.5
62	1955	b	33	27		5	1	
63								
64	1881	a	1430	1330		58		42
65	1880	a	207	207				
66	1960	c						
67	1902	a	112,800	112,800				96,000
68	1966	c	163	160		3		14
69	1920	b	2019	1550		375		

DATA
LAND APPLICATION FACILITIES

Ref. No.	Months Used	Average Flow (mgd	lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Ground Cover (acres) and Annual Return					
					Grass		Forest		Not Culti- vated	No Vege- tation
					Acre	Return	Acre	Return		
47	12	0.5		a						
48	10	6.0		e						
49	7	0.5		a,b,c						
50	4	0.4	920	a,c	40	$300				
51	6	2.0	9,585	a,d	160		5			
52	12	2-7		a,c,d						
53	12	0.5	100	a,c,d	30		30			
54	12	1.0		a,b,c						
55	12	3.0		a,d						
56	12	0.6		d						
57	12	4.3	1,300							
58	12	0.8		a,d						
59	12	5.0								
60	12	0.9		a,b,c						
61	12	0.4		e					103.5	
62	12	0.8		b,d						
63										
64		7-7-5		c,e						
65										
66	8	64.0		a,d,e	all					
67	12	256		a,d,e						
68	7	0.5		c	160		350			
69	4	4.5		a						

DATA
LAND APPLICATION FACILITIES

Ref. No.	Crop	Acre	Return	No. of Days/ Week Irri-gated	Application Rates in./hr. Max.	in./hr. Avg.	in./day Max.	in./day Avg.	in./wk. Max.	in./wk. Avg.	in./yr. Max.	in./yr. Avg.
47	Wheat Milo			7								
48	Alfalfa	780										
49	Wheat Bermuda						2.5				7.5	
50				7	0.22	0.22						
51				7	0.20	0.20						
52	Alfalfa Wheat											
53	Corn	30			0.17-0.25				2.0		104.0	
54	Wheat	80										
	Maize	100										
55	Maize											
56												
57	Bermuda	40	$10,000									
	Alfalfa	200										
	Milo	175										
	Cotton	175										
58				7								
59	Barley Milo Rye Oats	185	$76,700									
	Fescue	70										
	Alfalfa	100										
	Coastal Bermuda	385										
60	Maize Oats	80		5-6								
61				4	0.40	0.33		1.2		1.2		49.0
62	Corn Wheat	27	$840									
63												
64	X											
65	X			7	2.00				2.0	1.5	25.0	20.0
66				7								
67	Alfalfa	29,800		7								
	Corn	40,800										
	Wheat	23,700										
	Tomatoes	3,700										
	Chili	1,850										
	Flowers	240										
	Misc.	12,710										
68				7		2.00	1.0					24.0
69	Cotton Maize Coastal Bermuda	1,550	$17,000	7							24.0	16-18

DATA
LAND APPLICATION FACILITIES

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press. c) Tilling d) Overland Flow e) Ridge & Furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre	Year Purchased	Annual Cost Lease ($)	Term Lease (Year)	Value/land 1972 Est. ($/acre)	
							Facility	Adj. Land
47	f	N						
48	a	N						
49	a	N					1,000	1,000
50	a	N	200	1948			800	800
51	b	N	100- 350	1941 1951				
52	a	N					250	80-90
53	a	N		1962			500-1000	500-1000
54	a,e	N					1,000	500
55	e	N					1,000	1,000
56	a	N						
57	a	N	100	1920's 1930's 1950's		5	500	500
58	f	N					200	200
59	f	N		1955			500	500
60	a,f	N	0	1937			500	600
61	a	N	5	1947			5	5
62	f	N		1940			600	600
63								
64	other	N						
65	other	N						
66	b	N						
67	f	N					1,000- 1,340	17
68	b	N	1,500	1966			2,000	
69	border strip	Y	200	1960		annual	300	

DATA
LAND APPLICATION FACILITIES

	Land Application Facilities Capital Improvements					Operation and Maintenance Holding Ponds		
Ref. No.	Cost $	Year Made	Cost (mgd) $	Distance to Nearest Residence (Miles)	Annual Budget $	cap. (mgd)	area (acre)	Treatment at Site a) Aeration b) Chlorination c) Other
47				0.5				
48				Adj.		0		
49				0.02	0	0		
50	25,000	1951	62,000	0.16	5,000			b
51				0.1	6,000	3.7	2.3	b
52				0.2	2,300	30.0	18.0	
53	500,000	1972		0.25		0		b
54	0			Adj.			5.0	
55				0.25	0			
56		1962		0.02			2.0	
57	0				1,000	150.0	300.0	
58		1946		0.02		0.4	1.3	
59	204,700	1955		0.25	54,000	80.0	60.0	
60				0.01				
61	205,873	1972		5	5,000	20.8	12.0	
62	0			0.3	0		5.0	
63								
64				On-site			58.0	
65								c
66				Adj.				
67		1902		Adj.		0		
68			0.1			8.0	3.0	
69				Adj.		600.0	375.0	

DATA
LAND APPLICATION FACILITIES

Ref. No.	Land Used For			Security Used a) Fenced b) Accessable to Public c) Patrolled d) Posted e) Other	Residence On Premises	Recreation Use-Site	Public Health Restrict (Yes) (No)
	Farm	Graze	Other				
47	x	x		a	Y	N	Y
48	x	x		a	Y	N	N
49	x	x		a	Y	N	N
50		x		a,c,d	N	N	Y
51		x		a,c,d	N	N	Y
52	x			a,d	Y	N	Y
53					N	N	N
54	x	x		b	Y	N	N
55	x			b	Y	N	N
56			x	b		Y-Golf	Y
57	x	x		a	N	N	Y
58		x		a	Y	N	N
59		x		a,d	N	N	N
60		x		a,d	N	Y-Fish, Hunt	N
61				a,d		N	Y
62	x			d	N	N	Y
63							
64	x	x		a	Y	N	N
65	x			a		N	N
66				b		Y-Park	
67	x			b		N	N
68				b		Y-Golf	Y
69	x	x					Y

DATA
LAND APPLICATION FACILITIES

			System Performance						
			Monitoring Program				Effluent		
	Test Wells				Effluent				
Ref. No.	No.	Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Re-used	Re-apply	Dis-charge to Receiv-ing Water	Lost to Ground Water	Ground Water Interferes with Operation (Yes) (No)
47			b,c	d			x	x	N
48	0							x	N
49							x	x	
50	0		b,c	d,d	x				Y
51	0		b	d			x	x	Y
52	0		b	d				x	N
53	many	100-350	b,c,d,e,f	w,w,o,w o				x	N
54								x	N
55	0							x	N
56								x	N
57								x	N
58								x	N
59								x	N
60							x	x	N
61	1	178						x	N
62	0							x	Y
63									
64								x	N
65								x	N
66	0							x	N
67	0							x	N
68							x		
69	36	40-80	a,b	d,d			x	x	N

DATA
LAND APPLICATION FACILITIES
System Performance

Ref. No.	Data Available On a) Buildup/N b) Buildup/Heavy Metal c) Buildup/Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Quality g) Deterioration Receiving Water Quality h) Effect/Water Table i) Odors j) Health Hazards k) Other	Future Plans: Expand	Future Plans: Continue As Is	Future Plans: Decrease	Future Plans: Abandon	Information on Parameters Available: BOD mg/l To Land	BOD mg/l Groundwater	SS mg/l To Land	SS mg/l Groundwater	COD mg/l To Land	COD mg/l Ground-Water
47											
48		x				23		23			
49			x								
50			x			600		275			
51		x									
52	c		x			20-30		Trace			
53	a,b,c,d,e,f,g,h,i,j	x									
54	i		x								
55		x									
56	i		x								
57		x	x								
58			x								
59		x									
60			x								
61	a,f,h,j		x			15					
62		x						30			
63											
64	d		x			75			7-7.5		
65	none				x						
66						5-8					
67						300					
68			x								
69	a,c,f,h,i		x								

DATA
LAND APPLICATION FACILITIES
System Performance
Information on Parameters Available

	pH		Fecal Coli/100ml		P mg/l		Total N mg/l		Nitrate mg/l				Cl mg/l	
Ref. No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water
47														
48	7.6													
49														
50	6.5													
51														
52	6.7-6.5													
53														
54														
55														
56														
57														
58														
59														
60														
61	7.5													
62	0.1				7.5									
63														
64														
65														
66					5		0.5							20-30
67														
68														
69														

DATA
LAND APPLICATION FACILITIES

Descriptive Evaluation

			True Land Disposal				
Ref. No.	Operated by Agency? (Yes) (No)	Supple-mental Irrigation	As Irrigation	As Treatment Facility	Depth to Groundwatet Table (ft)	Average Slope Application Area (%)	Climate Class (APWA)
47	Y		x			3.5-4	B
48	N		x		100+	0-2	B
49	N		x		110	2-6	B
50	Y		x			2	C
51			x				C
52	N		x			<2	D
53	Y			x	100-350		D
54	N		x		200	2	B
55	N	x			8-14	<2	B
56	N		x			6	B
57	B		x		15	2	B
58	A		x		30	2	B
59	Y		x			2	B
60	N		x		20	<6	B
61				x		<2	D
62				x			D
63							D
64							E
65							E
66				x	30	1-10	A
67				x	30	0-2	A
68							A
69							B

LOCAL AGENCIES INTERVIEWED
DATA NOT TABULATED[1]

Climate Classification	Name	Reason
A	Barstow, California	Irrigate STP grounds only
A	Madera, California	Evaporation-Percolation
A	Porterville, California	Evaporation-Percolation
A	Visalia, California	Flow discharged to ditch – all
A	Whittier Narrows, California	Percolation
A	Yuba City, California	Evaporation-Percolation
D	Nantucket, Massachusetts	Evaporation-Percolation
D	Scituate, Massachusetts	Evaporation-Percolation
B	Gallup, New Mexico	Facility abandoned
B	Hobbs, New Mexico	Facility abandoned

[1] In addition, three facilities originally selected could not be interviewed.

DATA
LAND APPLICATION FACILITIES

B. Industrial

			Facility Data		
				Sludge Disposal	
Ref. No.	**Name City & State**	**Pop. Equiv. of Waste**	**Wastewater Treatment** **a) None** **b) Primary** **c) Secondary** **d) Tertiary** **e) Oxidation Ponds** **f) Effluent Chlorination** **g) Screening** **h) Other**	**Treatment** **a) Thickening** **b) Digesting** **c) Filtering** **d) Drying Beds** **e) Other**	**Disposal** **a) Irrigation** **b) Tank Truck** **c) Spreading** **d) Other**
1i	Green Giant Company Buhl, Idaho		g		d
2i	Western Farmers Association Aberdeen, Idaho	3,100	b	c	d
3i	Celotex Corporation Lagro, Indiana	8,400	b	e	d
4i	Commercial Solvents Terre Haute, Indiana	106,000	g		
5i	Chesapeake Foods Cordova, Maryland	5,500	g		d
6i	Celotex Corporation L'Anse, Michigan	73,500	b		
7i	Gerber Products Company Fremont, Michigan	39,200	b		
8i	Michigan Milk Producers Assoc. Ovid, Michigan	30,000	g		
9i	Simpson Lee Paper Company Vicksburg, Michigan	9,400	b		
10i	Green Giant Company Montgomery, Minnesota	120,000	g		
11i	Stokely Van Camp Fairmont, Minnesota	110,000	g		
12i	H. J. Heinz Company Salem, New Jersey	39,000	g,h		d
13i	Hunt-Wesson Foods, Inc. Bridgeton, New Jersey	245,000	g		
14i	U. S. Gypsum Company Pilot Rock Oregon		h		
15i	Weyerhaeuser Company Springfield, Oregon	30,000	c		c,d
16i	Pet Milk Company Biglerville, Pennsylvania	64,200	e,g		c
17i	Howes Leather Company Frank, West Virginia		e		
18i	American Stores Dairy Company Fairwater, Wisconsin		g		
19i	Libby, McNeill & Libby Janesville, Wisconsin	39,000	g		
20i	Idaho Supreme Potatoe Company Firth, Idaho		b		c,d

DATA
LAND APPLICATION FACILITIES
Facility Data

Ref. No.	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Type of Industry a) Canning b) Milk c) Refinery d) Pulp & Paper e) Inorganic f) Beverage g) Organic h) Food Processing i) Other	Year Start	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Total Area (acres) Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused
1i	1.0	1.0	a		c	135	135				
2i	0.5	0.5	a	1970	c	110	90				20
3i	0.18	0.37	i	1971	c	20	12.6	2.4	5.0		
4i	0.07		g	1965	c	160	110		1		49
5i	0.55	1.15	g	1972	c	40	38	1.5	0.5		
6i	0.6	1.8	d	1966	c	135	84	16	35		
7i	0.8	1.5	a	1953	c	153	90		3		60
8i	0.25	0.3	b	1964	c	95	26				69
9i	3.2	3.2	d	1971	c	480	80	380			
10i	1.2		a	1949	c	360	360				
11i	1.5	2.0	a	1950	c	415	400	15			
12i	1.3	2.16	a	1955	c	32	30		2		
13i	3.0	3.5	a	1961	c	75	44.1				30.9
14i	1.2			1954	c	420	380		40		
15i	0.5	0.648	d	1959-1960	c	100	75		25		
16i	Jan-Jun 0.103 Jul-Dec. 0.308	0.466	a,g	1941	c	59	50		9		
17i	0.015	0.144	i,Spent Tanning Solution	1972	c	16	10	2	2		2
18i	0.4		b	1962	c	200	25	75		25	75
19i	0.75		a	1952	c	50	50				
20i	0.63		h	1969	c	190	80				110

DATA
LAND APPLICATION FACILITIES

Ref. No.	Months Used	Average Flow (mgd)	lbs. Solid per Day	a)Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Ground Cover (acres) and Annual Return								
					Grass Acre	Grass Return $	Forest Acre	Forest Return $	Not Cultivated	No Vegetation	Crop	Acre	Return $
1i	2	1.0		a,b							Corn	90	
2i	9	0.5		a,c,f						90			
3i	12	0.18	4,000	a,b	1.5								
4i	12	0.07		a,c,d	50		50			60			
5i	12	0.55		a,d	38-40								
6i	6	0.6		d	100								
7i	12	0.8		d	90								
8i	12	0.25		d	26								
9i	12	3.2	700	d							Alfalfa Corn		150 150
10i	4	1.2		a,b,c	360								
11i	7	1.5	19,000	c	100	60							
12i	3	1.3		b,d	30								
13i	12	3.0	87,500	d	44.1								
14i	9	1.2		a,e	320								
15i	3	0.5		a	75	3,000							
16i	12	0.205		a,b	50								
17i	7	0.015		a	10								
18i	5	0.4		a,b	25								
19i	5	0.75		a,b	50								
20i	11	0.63		a,b	80				110				

DATA
LAND APPLICATION FACILITIES

Ref. No.	No. of Days/ Week Irrigated	Application Rates in./hr. Max.	Avg.	in./day Max.	Avg.	in./wk. Max.	Avg.	in./yr. Max.	Avg.	Waste Applied By a) Spray (low press.) b) Spray (high press.) c) Tilling d) Overland flow e) Ridge & Furrow f) Flooding g) Other	Renovated Water Collect (Yes) (No)	$ Cost Acre
1i	7									e	N	
2i	6							48	48	b	N	450
3i	7	0.18	0.18	1.1	0.53	7.7	3.68	384	184	b	Y	
4i	5	0.01	0.01	0.5	0.5	1.5	1	15	10	a	N	
5i	5									a	N	
6i	7	0.21	0.21	0.83	0.55	5.81	3.85	149	100	b	N	55
7i	5-6	1.0	0.5	24	12	144	72	2400	1200	b	N	
8i	7	0.58	0.58	0.42	0.35	3.0	2.5	150	124	b	N	
9i	7	0.77		5.9		8.2		4.3		b	N	400
10i	7	0.18	0.18	1.5	1.0	1.5	1.0	20.0	14.0	a	N	
11i	7			0.1		0.7		18.2		b	N	
12i	7						10			a	N	
13i	7	0.38	0.34	3.0	2.7	21	19	250	220	b	N	400
14i	7									a	N	200
15i	7			2.0	2.0					a	N	250
16i	6-7						2.0			a	Y	
17i	5									a	N	1000
18i	5	0.14	0.017	2.25	0.41	6.3	2.9	42.0	42.0	b	N	110
19i	6	0.44	0.019	0.8	0.46	3.24	3.24	47.0	47.0	b	N	250
20i	7				0.3					b	N	600-800

DATA
LAND APPLICATION FACILITIES

Ref. No.	Year Purchased	Annual Cost Least ($)	Term Lease Year	Value/Land 1972 Est. ($/acre)		Capital Improvements			Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green Belt f) Other			Distance to Nearest Residence (Miles)
				Facility	Adj. Land	Cost $	Year Made	Cost (mgd) ($)		Facility	Adj. Prop.	
1i		55/acre		1,000	1,000	1,200	1963	1,200	c	x		0.03
							1964		d		x	
2i	1971			450	450	95,000	1971	190,000	d		x	0.03
3i	Prior to 1940			1,000	1,000	120,000		670,000	c		x	0.04
							1970		f		x	
4i	1960-65			750	750				d		x	
5i				800	800							0.06
6i	Prior to 1955			100	100	450,000	1965	250,000		x	x	4.00
7i	Prior to 1953			300	300	75,000	1953	93,000	d	x	x	Adj.
8i	1937			350	350		1964		d	x	x	1.00
9i	1960-72			400	400	140,000	1971	43,750	d	x	x	1.00
10i				400	400	72,000	1949		d	x	x	Adj.
11i	Pre 1950			650	650	100,000	1965-72	DNA	d	x	x	1.00
12i				800		100,000	1955	90,000	d	x	x	0.10
13i	1961			600	600	240,000	1961	68,000	d	x	x	0.20
14i	1953			500	500	NA			d		x	0.20
15i	1965					10,000		20,000	a		x	0.02
							1966-72		c	x		
16i				100	100							0.10
17i	1971			1,000	300	40,000	1971-72	NA				0.30
18i	1942			400	500	6,000	1955	15,000	d	x	x	0.20
19i	1952			1,500	1,500	60,000	1952	80,000	d	x	x	
20i	1969-71											0.20

DATA
LAND APPLICATION FACILITIES

Ref. No.	Annual Budget $	Holding Ponds		Treatment At Site a) Aeration b) Chlorination c) Other	Land Used For			Security Used a) Fenced b) Accessable to Public c) Patrolled d) Posted e) Other	Residence On Premises	Recreation Use Site	Public Health Restrict (Yes) (No)	Test Well	
		Cap. (mgd)	Area (acre)		Farm	Graze	Other					No.	Depth (ft.)
1i								a	Y	N	Y	0	
2i	25,000							a	N	N	Y	4	30
3i	6,000	6.2	5.0	c				a,e	N	N	N		
4i		0.17	1.0					a		N	N	7	10-25
5i		0.25	0.5					b	N	N	N		
6i	25,000	125.0	35.0	c					N	N	N		
7i	65,000	24.0	3.0	c				b	Y	N	N	N	
8i	0							a	N	N	N	N	
9i	35,000							a	N	N	N	16	6-45
10i	28,000							b				0	
11i	23,000	20.0	15.0					b		N	N	N	
12i								a,b	N	N	N	2	5
13i	40,000	0							N	N	N	0	
14i	28,526	120.0	40.0			x		a,d	N	Y-game hunting	N	N	
15i						x		a,d	N	N	N	N	
16i			9.0					a,d	Y	N	N		
17i		35.0	2.0					b	N	N	N	N	
18i	4,500	0							N	N	N	0	
19i	2,750	0							N	N	N	N	
20i		0						b		N	Y 2	10	

DATA
LAND APPLICATION FACILITIES

	Monitoring Program		System Performance						
Ref. No.	Test For a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Re-used	Re-apply	Discharge to Receiving water	Lost to Ground-Water	Ground Water Interferes with Operation (Yes) (No)	Data Available On a) Buildup/N b) Buildup/Heavy Metal c) Buildup/Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Quality g) Deterioration Receiving Water Quality h) Effect/Water i) Odors j) Health Hazards k) Other	
1i							x	N	i
2i	a,b,c,d	d,d,o,w				x	N	a,f,h,j	
3i	d	d			x	x	Y	f,g	
4i						x	Y	d,i	
5i	a,b,d	o,o,o				x	N		
6i					x	x	N		
7i						x	N		
8i						x	Y		
9i	a,b,c,d,e	d,d,y, monthly, ea. cutting				x	N	a,b,c,d,f,h,i,j	
10i						x	N	c,h	
11i	a,b,c,f	-,w,w			x		N	a,g,i,k	
12i	a,b	5/w,5/w	x						
13i	a,b	w,w				x	Y	j	
14i	a	o				x	N	d,e	
15i	a,b,c,e	d,d,d				x	Y	a	
16i	a,b,g	w,w,d		x	x	x	N		
17i						x	N		
18i						x	N		
19i						x	N		
20i						x	Y	h	

DATA
LAND APPLICATION FACILITIES

Ref. No.	Future Plans Ex- pand	Future Plans Con- tinue As Is	Future Plans De- crease	Future Plans Aban- don	Information on Parameters Available BOD mg/l To Land	BOD mg/l Ground- water	SS mg/l To Land	SS mg/l Ground- water	COD mg/l To Land	COD mg/l Ground- water	Ph To Land	Ph Ground- water	Fecal Coli/100 ml To Land	Fecal Coli/100 ml Ground- water
1i	x													
2i	x								3,719					
3i		x												
4i		x			30,000		40,000							
5i		x			200	2								
6i		x												
7i		x												
8i		x												
9i		x												
10i	x				2,100		2.92							
11i	x													
12i					200	2					4.3	4.3		
13i	x													
14i		x			460						6.3			
15i		x			1,200				3,000		8.5			
16i		x					56		1,400		6-9			
17i		x												
18i		x												
19i		x			1,060		520		1,800		7.0			
20i		x												

DATA
LAND APPLICATION FACILITIES
System Performance

	Information on Parameters Available										Descriptive Evaluation		
	P mg/l		Total N mg/l		Nitrate mg/l		Nitrite mg/l		Cl mg/l				
Ref. No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	Depth to Ground-Water Table	Average Slope Application Area (%)	Climate Class (APWA)
1i													V
2i													V
3i												<2	IV
4i											5-10	<2	IV
5i												2-6	III
6i													V
7i											37	<2	V
8i												<2	V
9i											8-15	<2	V
10i												2-6	V
11i											10	2-6	V
12i											4.5-11		IV
13i											4-40	2-6	IV
14i												5-10	IV
15i	Trace		<20						<10			<2	III
16i	0.9		2.0		0.01		0.9		133.7		1.5-3	0-3	IV
17i													IV
18i											80	2-6	V
19i													V
20i			124	38	4	32							

APPENDIX D
MAIL SURVEYS OF LAND APPLICATION FACILITIES

Information was requested from Municipal and Industrial Operators of land application facilities. The standard questionnaire, Appendix A, was used. This appendix contains a tabulation of the replies.

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LAND APPLICATION FACILITIES
MUNICIPAL

Ref. No.	Agency and State	Pop. Served	Pop. Equiv. of Waste	Community Data Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Year Started	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other
1	City of Winslow, Ariz., WW Plant	8,500	10,700	b,e	0.83	1.75		a,c
2	City of Banning, Ca.	12,000		b,c,e,f	0.6	2.2	1941	b
3	City of Brentwood, Ca.	3,000		c,f,g	0.25	0.27	1941	b
4	Buellton Comm. Dist., Ca.	1,500		c	0.015-0.02	0.3	1960	b
5	City of Coalinga, Ca.	6,000		b,e	0.75	2	1963	
6	City of Corning, Ca.	3,500	3,500	b,e,f	0.3	1.0	1950	b
7	City of Corcoran, Ca.	6,000	6,000	b,c,f	0.76	1.5	1962	c
8	Co. Dept. of Honor Camps, Ca.	Varied		c	0.015	0.02	1965	c
9	Cutler Public Utility Dist., Ca.			c,e	0.4	0.8	1960	b
10	City of Dixon, Ca.	4,740		e	0.5	5.31 AF/D	1968	b
11	City of Elsinore, Ca.	4,000		e	0.25	0.50	1920	c,d
12	Dept. of Parks & Rec., San Diego, Ca.			c	0.002	0.006	1968	a
13	Eastern Mun. Water Dist., San Jacinto, Ca.	30,000	30,000	c	2	2.5	1965	c
14	City of Escalon, Ca.	2,500		b	0.25	1.5	1940	b
15	Fallbrook San. Dist., Ca.	6,500	6,500	c	0.65	.625	1955	c
16	City of Greenfield, Ca.	2,950		b,e	0.22	0.25		
17	City of Gridley, Ca.	3,620	7	b,e	1.7	2	1951	c,d
18	City of Hanford, Ca.	16,000	16,000	b,e	2	3		b
19	City of Healdsburg, Ca.	5,700		e	0.55	2	1962-68	b
20	City of Kerman, Ca.	2,800	2,800	b	0.3	0.3	1950	a,b
21	City of Kingsburg, Ca.	4,110		c,d	0.5	1.75		b,c
22	City of Leucadia, Ca.	6,000		b,c,e,f	0.6	0.75	1962	c
23	City of Loyalton, Ca.	945		e	0.24	1.2		c
24	Milpitas San. Dist., Ca.	34,000	30,600	b,c,f	3.0	3.6		
25	Napa San. Dist., Ca.	55,000	7,500	c,e	5	11		

LAND APPLICATION FACILITIES
MUNICIPAL

	Total Acres												
Ref. No.	Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused	Months Used	Av. Flow (mgd)	Lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Depth to Groundwater Table (ft)	Average Slope Application Area (%)	Climate Class (APWA)
1							12						
2	3.75	1.50					12	0.6	197	d,e			B
3	15	10		5		10	2	0.2		c,d	15	1	A
4	8						12	0.015-0.2		d,e	30-50	Flat	A
5													A
6	40	40	10	4	0	0		0.3±	49	b,c	20±	0.5	A
7	120	85±	0	35	20	22	10	0.76		c,d	10	1	A
8	Varied						12	0.015					A
9	75	75		3	2	80	12	0.35		d	38	5	A
10	50					110	12			c	15	0.2	A
11	300±	65		1	4	200	12	0.25		a,d	20	2-3	A
12	2.5	1.5				1	Occ.	0.002	<30			5	A
13	380	25					12			d	180		A
14	11				11		12	0.25		a		0	A
15	43	20-30				10-20	12		10-90	a	0-20	5	A
16													A
17	12		2	6	1.5	28	12	1.70		d,e			A
18	215	155	20	55	155		12	2.0	350	c	100	0.3	A
19	28	10		8	20	20	2	0.5		a	40	0.5	A
20	40±	40									80	0.10	A
21	110						12			d	6	Flat	A
22	240	240		3	3		11	0.6		a,e	2	1-2	A
23	5	10				2	12			a	7	Level	A
24													A
25													A

LAND APPLICATION FACILITIES
MUNICIPAL

	Ground Cover (acres) and Annual Return								Application Rates							
Ref. No.	Grass Acre Return	Forest Acre Return	Not Cultivated	No Vegetation	Crop	Acre	Return $	No. of Days/ Week Irrigated	in./hr. Max.	in./hr. Avg.	in./day Max.	in./day Avg.	in./wk. Max.	in./wk. Avg.	in./yr. Max.	in./yr. Avg.
1	x		x													
2	1							2			20M gpd					
3	10		10	5		4		20M		0.2		0.8		25/yr		
4																
5																
6					Olives Pasture	20 20		7±								
7					Alfalfa	85		2								
8	x							Daily								
9					Cotton Grapes	70										
10				x												
11								7	39,000							
12	1.5	1.0						Occ.								
13					Pasture Alfalfa, Beets			7								
14																
15					Avocado Lemon	8 8	2,000 6,000	4								
16																
17	28		12													
18				80		155	3,500									
19																
20					Alfalfa Cotton	40										
21																
22								6								
23								1								
24																
25																

LAND APPLICATION FACILITIES
MUNICIPAL

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press.) c) Tilling d) Overland flow e) Ridge and furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre $	Year Purchased	Annual Cost Lease $	Term Lease (Year)	Value/Land 1972 Est. ($/acre) Facility	Value/Land 1972 Est. ($/acre) Adj. Land	Capital Improvements Cost $	Capital Improvements Year Made	Cost (mgd)
1	a,b	N									
2	a	N		1941							
3	b	N	300	1940			3,000	3,000			
4	b	N	1,345	1959-1969			1,345	1,345			
5		N									
6	b,c	N									
7	c	Y (Reirrigation)	100	1958	400	4	1,000	1,000	15,500	1962-71	
8	a,c	N		1950							
9	c	N		1960-1965		5	9,000	1,000			
10		N	750	1966			45,200				
11	a	N									
12	a	N									
13	a	N									
14		N		1930			1,200	1,200	13,000	1972	
15	a		4,500	1970			4,000	4,500			
16											
17	b	N	1,000	1950			3,000	3,000			
18	c	N	900	1972			900	900	170,000	1972	
19	b	N	3,500	1969			3,500	3,500			
20	c	N	1,000	1965	700						
21	b	N	350				1,000	2,000	15,000		
22	a	N					50,000	100,000			
23		N									
24											
25											

LAND APPLICATION FACILITIES
MUNICIPAL
Operation and Maintenance

Ref. No.	Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green Belt f) Other	Facility	Adj. Prop.	Distance to Nearest Residence (ft.)	Annual Budget $	Cap. (mgd)	Area (acre)	Treatment At Site a) Aeration b) Chlorination c) Other	Land Used For			Security Used a) Fenced b) Accessible to Public c) Patrolled d) Posted e) Other
									Farm	Graze	Other	
1					19,500	23.6	18	No		x		a
2				2,500	64,000	4.5	3.5	b				a,d
3	d	x	x	2,500	30,000	30	5			x		a,d
4	d			1,000				a				a
5	d		x	3,000								
6	d	x	x	1,000		7	4		x			a,c
7	d			5,280			35	a	x			a,d
8				5,000	9,000		<1	a				d
9	d	x	x	1,800	4,000		4	a,b				e
10	d	x	x	300	8,000							a,d
11	a	x					30	No				a,d
	d	x				6	4	a	x			a,c,d
12	e	x	x	5,000	3,800		<1	a	No	No	No	a,d
13	d	x	x			19	19.5	a	x			a
14	d	x	x	1,000	13,500	11			x			a
15	a	x	x	1,000				a,b	x			a
	b	x										
16						1.68	8		No			a
17	c		x					a	No			a,d
	d	x	x									
18	c	x	x	1,500	45,000	55			x			a,b
	d		x									
19	d	x	x	500	43,000	12	20	a,b	x			a
20	c	x			8,000				x			b
	d		x									
21	d	x	x	3,500	5,000			a				a
22	f					10		a,c			Golf Course	b,c
23				2	23,050					x		a,e
24												
25												

LAND APPLICATION FACILITIES
MUNICIPAL

Ref. No.	Residence on Premises	Recreation Use Site	Public Health Restrict (Yes) (No)	Test Well No.	Test Well Depth	Operation and Maintenance Monitoring Program Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Ve. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Are Underdrains Used (Yes) (No)	Reused	Reapply	Effluent Discharge to Receiving Water
1	Yes/Golf	Golf		None				N			
2	No	None				c	d	N			
						d	w	N			
3	No	None	None			c	2/d	N			
						d	2/d				
4	No	None	Yes (odor)			c	y	N			
5	No	None						N			
6	No	None	Yes					N			
			(runoff not permitted)								
7	No	None	Yes			c,d	1/d				
			(Mosquito			c,d	o				
			coated)			e	2/y				
						f	1/y				
8		None	Yes			c	o	N			
			(Health			d	2/y				
			hazard)			f	2/y				
9	1							N			
10	No	None	Limited					N			
11	No	None	Yes			c	d	N			
			(Backflow			d	d				
			prevention)								
12	No	No	Yes			c	o	N			
						d,f	2 yrs.				
13	No	No		1	700	c,d	d	N			
						f (on request)					
14	No	No	No			None		N			
15	Yes	No	Yes			a	y	N			
			Co. & St.			b, 50 & 60					
						f, 4 yrs.					
						e, spot					
16	No	No	No			c,d	monthly	N			
17	No	No	Yes	9	15	c, Mon.; d, Mon.		Y			x
			(No admit.)			e,f,g, 3 yrs.					
18	No	No	No	None		c,d	d				
19	No	No						N			
20	No	No	No			c,d,e	y	N			
21	No	No	No			None		N			
22		Yes				c,d,e		N			
23								N			
24											
25											

LAND APPLICATION FACILITIES
MUNICIPAL

	Effluent		System Performance								
			Data Available On	Future Plans				Information on Parameters Available			
								BOD mg/l		SS mg/l	
Ref. No.	Lost to Ground-water	Ground-water Inter-feres With Opera-tion (Yes) (No)	a) Buildup/N b) " Heavy Metal c) " Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Qual. g) Deterioration Receiving Water Qual. h) Effect/Water Table i) Odors j) Health Hazards k) Other	Ex-pand	Con-tinue As Is	De-crease	Aban-don	To Land	Ground-water	To Land	Ground-water
1		N	No		x			270 ppm	30-80 ppm		
2		N	No	x				120 ppm		197	
3		N	No								
4		N	Yes	x							
5		N	No		x					NA	
6		N	No	x				138	88		
7		N	j							NA	
8		N	c,f,g,i,j		x			<250	<30	<250	<30
9			No		None						
10			No	x	x					NA	
11		N	i,j	x				200	15-20	5-7	<05
12		N	c,f,g,i,j	x				NA	30		
13		N	b,h,i,j	x				270	65	280	50
14		N	No	x							
15				x							
16		N	No	x				210	270		
17		N	d,f,g	x				250	170		
18		N	d,i	x				1,050	40	285	111
19		N	i	x							
20		N	a,b,c,g	x				205	113	192	88
21		N	No	Ponds with treatment to be relocated							
22		Y	b,d				x	200	15	180	18
23		Y	h		x						
24											
25											

LAND APPLICATION FACILITIES
MUNICIPAL

System Performance

Information on Parameters Available

Ref. No.	COD mg/l To Land	COD mg/l Ground-water	pH To Land	pH Ground-water	Fecal Coli/100 ml To Land	Fecal Coli/100 ml Ground-water	P mg/l To Land	P mg/l Ground-water	Total N mg/l To Land	Total N mg/l Ground-water	Nitrate mg/l To Land	Nitrate mg/l Ground-water	Nitrate mg/l l To Land	Nitrate mg/l l Ground-water	Cl mg/l To Land	Cl mg/l Ground-water
1			8.5±	8.5												
2			8.8									9 ppm				
3			7.7													
4																
5																
6			7.3	7.3												
7																
8					30/100											
9																
10																
11																
12																75
13	385	88	7.2	7.3					42	30		0.2			180	135
14							None							None		
15																
16			7.2	6.0							448	18.2			375	185
17				7								0.2				0.69
18			7.5	7.5												
19			7.8	7.6		<2.2										
20			7.1	6.9			38	37	42	34					0	0
21																
22			7.2	7		2.2				6.3		11				367
23																
24																
25																

LAND APPLICATION FACILITIES—Municipal **Community Data**

Ref. No.	Agency and State	Pop. Served	Pop. Equiv. of Waste	Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Year Started	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other
26	City of Patterson, Ca.	3,743		b,d,e	0.75	0.5	1960	a,b
27	City of Pinedale, Ca.	5,000		b,c,e	0.75	1	1963	c
28	City of Pixley, Ca.	1,200					1951	b
29	Pomerado Co., Ca. Water Dist.	13,500		c,e,f	1.1	1.5	1972	c
30	City of Paso Robles, Ca.	8,000		c,e,f	1.2	2.2		b
31	City of Reedley, Ca.	8,400	4,000	c	1.1	1.45		b,c
32	City of Ripon, Ca.	2,700		b,e	0.3	0.35	1925	b
33	City of Riverbank, Ca.	4,000	4,000	e	0.4	0.6	1949	b
34	City of Riverside, Ca.	140,000	180,000	b,c,f	17.5	25	1947	b
35	San Bernardino Co. Special Dist. Div., Ca.	6,500		b,e,f	.5	.75	1947	c
36	San Juan Bautista, Ca.	1,200		e	2.8	7.2	1923	b
37	City of Santa Paula, Ca.	18,301		c,f	1.5	2.7		b
38	City of Santa Rosa, Ca.	2,000		d	0.14	0.68	1973	c
39	City of Soledad, Ca.	5,000	5,000	b	0.4	0.5	1934	a
40	Strathmore Public Utility Dist., Ca.	±2,200		b,e	0.2	0.22	1950	b
41	Terra Bella Sewer Main Dist., Ca.	1,000		b			1960	b
42	City of Tipton, Ca.	969		e			1962	b
43	City of Tulare, Ca.	16,900	18,368	b,c,e	2.6	3.0	1922	b
44	City of Tuolumne, Ca.	1,200-3,500		b,c,e,f	0.135	0.35	1966	c
45	Valley Center Munic. Water Dist., Ca.	100	17 lbs./d	c,f	0.00145	0.09	1968	c
46	Waterford Comm. Serv. Dist., Ca.	3,000	3,000	e	0.3	0.6	1957	b
47	Westwood Comm. Serv. Dist., Ca.	2,060	350 lbs./d	b	0.86	1.3	1970	b
48	Wheatland Dept. of Public Works, Ca.	1,500	255 lbs./d	b,e	0.15	5	1968	c
49	City of Woodland, Ca.	23,000	92,000	e	7	15	1890	a,b,c
50	City of Scott City, Ks.	4,325		b,c	0.432 300 gpm	0.4	1971	c

LAND APPLICATION FACILITIES–Municipal

Ref. No.	Used	Irri- gation	Buffer	Onsite Storage	Onsite Treat- ment	Un- used	Months Used	Av. Flow (mgd)	Lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Depth to Ground- water Table (ft)	Average Slope Appli- cation Area (%)	Climate Class (APWA)
26		20	25	25	25	None	12	0.75	0.3	c,d		15	A
27	17	None		10	7	10	12	0.75		d	110	6	A
28	57.11	30		8						a	200		A
29	20	20	40			20				d,e	10-15	20	A
30	15			10	5	20	12	1.2	Trace	c,e	10	5	A
31	41	38				0	12	1.1	13.4	d	20	Level	A
32	12					12	12	0.3		a,d			A
33	30			24	6		12	0.4	320	a,d	12	1	A
34	73					73	12	17.5					A
35	98.5	60	None	38.5		None	12	0.5		e	18	5	A
36	5			1	2	2	12	2.8	176	a,e	60	15	A
37	0.1	0.1					3±	0.02		b	7	0.2	A
38	120	120				140				a		0-5	A
39	100	15	20	10	2	53	12	0.4	150	d	5(min.)	1	A
40	7	36		4	4		7	0.125		a	75		A
41	20	10		2	1		12			a	150		A
42	40	30				10	12			a		1	A
43	780	665	0	83.5	25.4	6.9	12	2.6	50	d	90	0.2	A
44	26	26	32	2±	6	32	12	0.135	200	c	175	18-23	A
45	15	15		5	2	12	10	0.00145		a	10	20	A
46	20		15	3	5	20	12	0.3		a	1		A
47	27				27		12	0.86		b,d	6 in-1 ft	1	A
48	15	None	4	7	4	None	12	0.15		d,e	30	0.2	A
49	960	900		124	124	330	8	6		c	2-10	.0005	A
50	25						12			a			D

LAND APPLICATION—Municipal

Ref. No.	Ground Cover (acres) and Annual Return: Grass Acre Return	Forest Acre Return	Not Cultivated	No Vegetation	Crop	Acre	Return $	No. of Days/ Week Irrigated	Application Rates: in./hr. Max.	in./hr. Avg.	in./day Max.	in./day Avg.	in./wk. Max.	in./wk. Avg.	in./yr. Max.	in./yr. Avg.
26								2								
27								None								
28	30		27					5	0.02	0.01	0.04	0.3	2.8	2.2	147.4	112.7
29			20					None								
30	2		30					7								
31				38												
32																
33				30				NA								
34								None								
35																
36					Alfalfa	0.1		1	0.5				0.25			
37																
38								7	NA				2			
39			x	x	Citrus	4		6								
40	32															
41	20															
42								7	0.008	0.19			1.33		69.16	
43					Cotton, Corn, Alfalfa, Milo			7	0.8	2	3.1	8	7	5.6	292	
44								1 hour per month								
45																
46	10		10					NA								
47	27															
48	2		5	8												
49					Safflower	620	10,000									
50	10				Milo, Sudan grass, Rice											

LAND APPLICATION FACILITIES–Municipal

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press.) c) Tilling d) Overland flow e) Ridge and furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre $	Year Purchased	Annual Cost Lease $	Term Lease (Year)	Value/Land 1972 Est. ($/acre) Facility	Adj. Land	Capital Improvements Cost $	Year Made	Cost (mgd)
26	b	N	1,000	1960			2,000	2,000			
27		N	2,500	1963				3,000	2,500	1963	
28	b	N		1948			30			1948	30
29	a	N	800								
30		N	NA	1948			800	900	1 mil.	1970	
31		N	3,500	1968			3,500	3,500			
32							1,000	1,000	20,000	1970	
33				1948					45,000	1972	
34	NA										
35		N	2,000	1947			15,000	20,000	22,000	1972	
36		N				99	15,000		15,000	1971-72	
37	b	N									
38	a	N									
39	b,c	N	100	1966			150	200	100,000	1955	
40	b,c			1949				3,000	72,000	1949	
41	a	Y	0	1913			300	500	2,000	1913	
42	b	Y		1960		30					
43	c	Y					800	800	250,000	1949	
44	a	Y		1964 & 1969							
45	a	Y		1965- 1971		5,000	5,000	150,000		1965- 1971	
46		Y		1957					6,000	1972	
47	NA	Y	200	1971							
48	b	Y	1,500	1968			3,500	3,500	268,000	1968	
49	b,c		100 to 500	1930 1960-64			600	800			
50	b	N	412.50	1968	1						

LAND APPLICATION FACILITIES–Municipal – Operation and Maintenance

Ref. No.	Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green Belt f) Other	Facil-ity	Adj. Prop.	Distance to Nearest Residence (ft.)	Annual Budget $	Cap. (mgd)	Area (acre)	Treatment At Site a) Aeration b) Chlorination c) Other	Land Used For			Security Used a) Fenced b) Accessible to Public c) Patrolled d) Posted e) Other
									Farm	Graze	Other	
26	d	x		2,640	25,000		308	a,b				a
27	a,b,c			2,000				a				a,e
28				800						x		
29	d	x		12,000	50,000	0.5		a,b		x		a
30						5.9	10	b				a,b
31	d		x	1,000	27,445	None						a
32	c,d	x	x	1,200	22,000			a				a,b
33	d	x	x	800	9,500		24	a				a
34						N.A.						
35	b		x									
	c	x	x	2,500	7,800							
36	a,e			400	10,000	82.3	38.5	a,b				a,d
37	d	x	x	200		8		a,c		x		a,c,d
38	a	x		50		5		b				b
39	d	x	x	1,000								d
40	d	x	x	800	7,240	3		a	x	x		a,d
41	d	x	x	400	2,500	2				x		a
42												
43	d	x	x	1,280	60,495	19.5	20		x			a,b
44	a,b,e	x		50	29,337	4	2		x			a,b
45	a	x	x		5,000	76	18	a,b				a,d
46	a		x	200	4,000	3						a
	d	x										
47				3,000		44	27			x		a,d
48	d	x	x	1,000	12,000	15	7±	a				a,c,d
49	d	x	x	6,000	50,000		364		x			a,c,d
50	d	x		1,300	15,835		27	a	x			

LAND APPLICATION FACILITIES–Municipal

	Operation and Maintenance					Monitoring Program			Effluent		
Ref. No.	Residence on Premises	Recreation Use Site	Public Health Restrict (Yes) (No)	Test Well No.	Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) VegAnalysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Are Underdrains Used (Yes) (No)	Reused	Reapply	Discharge to Receiving Water
26	No					c,d	d				x
27	No	No						N			
28											
29	No		Yes (Cal. use of water–STD)			d f	d w	N			
30	No	No	No			c,d f	d 2 yrs.	N			
31	No	No	No			a,c,d	w				
32	No	No	No			c,d	4 yrs.	N			
33		No	No					N			
34			N.A.								
35		No	No	None		c,d	monthly				
36	No					c,d		N			x
37	No										
38		No						N			
39	No	No	Yes No discharge	None		c,d	monthly	N			
40											
41	No	No	Yes (State & Co.)					N			
42											
43	No	No	No			c,d	d				
44			Yes (No spill)					N			
45	No	No	Yes (Sprinklers, etc. not for drinking)	1	6	d	monthly				
46	No	No	No					N			
47	No							N			
48	No	No	Yes (Posted against usage)	None		c,d,f	w				
49	No	No						N			
50											

LAND APPLICATION FACILITIES—Municipal

System Performance

Ref. No.	Effluent Lost to Groundwater	Groundwater Interferes With Operation (Yes) (No)	Data Available On a) Buildup/N b) " Heavy Metal c) " Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Qual. g) Deterioration Receiving Water Qual. h) Effect/Water Table i) Odors j) Health Hazards k) Other	Future Plans				Information on Parameters Available			
				Expand	Continue As Is	Decrease	Abandon	BOD mg/l		SS mg/l	
								To Land	Groundwater	To Land	Groundwater
26											
27		N	a,b,c								
28											
29		N	a,c,f,g,h,i,j	x					38		37
30		N		x				271	10.6	162	Trace
31		N	None	x				116	33	165	31
32		N	None	x							
33		N	None		x			250		320	
34					x			212	25	250	25
35		N	i,j					300	2-10	500	5-20
36		N	a,b,c,g,i,j	x				150	22	13	34
37		N	i,j		x			93	82		76
38		N	g		x			74			
39		Y (Reduce infiltration rate)	i,j	x				300	150	300	150
40		N	f		x						
41		N		x							
42											
43				x				144		138	
44		N	d,e,f,g,h,i,j	x							
45		N	i,j			x (Facility to be built)			3.5		2.3
46		N		x	x			250			
47			h		x						
48		N	d,e,f,g,h,i,j,k	x				280	None		
49			d,e,f,g,i,j	x				100-80	<20		
50		N	i		x						

LAND APPLICATION FACILITIES–Municipal – System Performance

Information on Parameters Available

	COD mg/l		pH		Fecal Coli/100 ml		P mg/l		Total N mg/l		Nitrate mg/l		Nitrite mg/l		Cl mg/l	
Ref. No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water
26			6.6-7.6													
27																
28																
29				7		-3										395
30			7.5	7.5		<4.5										
31			7.6	7.8												
32																
33																
34				7.8		2-5						20				
35			7.3	9.0	NA		35.0	1	NA		0	5.6	0.0	0.006		NA
36	425	179		7.7								0.06				
37																
38			7.0		2.8											
39			7.2	7.2												
40																
41																
42																
43	300		6.8					11.2	7.38		5.30		x		30	
44			Yes													
45				8.0						3.02		2.2	0.82			190
46																
47																
48			7.5	7.5											0	0
49			7.5	8.5-9.5												
50																

LAND APPLICATION FACILITIES–Municipal

				Community Data				
Ref. No.	Agency and State	Pop. Served	Pop. Equiv. of Waste	Wastewater Treatment a) None b) Primary c) Secondary d) Tertiary e) Oxidation Ponds f) Effluent Chlorination g) Other	Average Sewage Flow (mgd)	Max. System Cap. (mgd)	Year Started	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other
51	City of Sublette, Ks.	1,333		e	0.13	0.4	1968	c
52	Village of Cassopolis, Mi.	2,100			0.015	0.31	1966	b
53	City of East Jordan, Mi.	2,041		b,e,f	0.25		1972	c
54	Harbor Springs Area Sewage Disposal Auth., Mi.	3,500		e,f	0.5		1972	c
55	City of Harrison, Mi.	1,500		e	0.07	0.14	1971	c
56	Village of Middleville, Mi.	1,865		e	0.025		1970	c
57	Ottawa Co. Rd. Comm., Mi.	80	80	e	0.008	0.01	1969	c
58	Village of Roscommon, Mi.	808						c
59	City of Helena, Mt.	24,000		b	3	10	1960	b
60	City of West Yellowstone, Mt.	Winter 1,000 Summer 15,000		b,c	0.5	2.5	1966	c
61	City of Grant, Ne.	1,100		e	0.171		1960	b
62	City of Winnemucca, Nv.	3,900	663	e	0.35	0.80	1964	a
63	City of Lovington, N.M.	10,000		b,c	0.5	3	1950	a
64	City of Dickinson, N.D.	14,000		e	1		1962	c
65	Boise City, Ok.	1,980		a	0.001	0.002	1970	b
66	City of Bend, Or.	1,500	3,600	b,c,f	0.5	2.0	1970	a,b
67	City of Cofulla, Tx.	3,900		b,e	0.165			b,c
68	City of Coleman, Tx.	5,608		b,c	0.3	1		a
69	City of Comanche, Tx.	5,000		b,f	0.4	0.72	1972	d
70	City of Dalhart, Tx.	5,700		b,c	0.64	1	1971	a,b
71	City of Denver City, Tx.	4,200		e	0.15	3	1949-1958	c
72	City of Elsa, Tx.	5,000		b,c,e	0.18	0.21	1948	b
73	City of Goldthwaite, Tx.	1,700	1,640	b,e	0.2	0.1	1936	b
74	City of Idalou, Tx.	1,800		b,c,e				b
75	City of Kingsville, Tx.	6,590	4,481		3	3.1		
76	City of LaMesa, Tx.	11,559	8,823	b,c,e,f				
77	City of Morton, Tx.	3,760		b,c,e				c
78	City of Munday, Tx.	1,700		b,c			1952	
79	City of Ralls, Tx.	2,100	1,000	b,d	0.1	0.35	1958	b,c
80	City of Raymondville, Tx.	7,986		c,f	0.87	1.0		
81	City of San Saba, Tx.	2,555		b,c,e	0.126	0.166	1954	a,c
82	City of Seagraves, Tx.	2,500		b,c,e	0.2	0.35	1950	c
83	City of Van Horn, Tx.	3,000			0.15			
84	City of Winters, Tx.	2,907	0.49	b	0.154	0.2	1930	b
85	City of Soap Lake, Wa.	1,100		c,f	0.11	0.5	1946	b
86	City of Spring Green, Wi.	1,200		b			1939	

LAND APPLICATION FACILITIES–Municipal

	Total Acres												
Ref. No.	Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused	Months Used	Av. Flow (mgd)	Lbs. Solid per Day	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other	Depth to Groundwater Table (ft)	Average Slope Application Area (%)	Climate Class (APWA)
51	40	8	12.7	4.5	1.8	20	12			c			D
52	160	60	30	22	22	40	5	0.250		c,d,e	37	30	E
53	176	50	105	21		249				b,c,d	5.31- 23.29	5	E
54	20				4.2	13	12			d,e			E
55	62	20				63	12	0.025		d,e	200	4	E
56	3	3	10	0.5	1	0	7	0.0075		d,e	32		E
57	120	40			80	40	12			c	20	1	E
58	17						3	2	30				E
59										a	12	3	E
60	8			16.75	8	16.75	12	0.3		d	30		E
61	24						12			a,d			D
62	20	80	6	0	14	0	12	0.35	125	b	0-48 in.	0.01	B
63	160						12	0.5			75		B
64	400	Yes					5				120		E
65	40			27		27	12	0.001			240	Flat	C
66	40	3	35	0	2	35	5	0.5	10		700	3	C
67	12			12	12		12	0.165		a	3	30	B
68	106	75		10	10	15	12			a	13	3	C
69	12						12			c,e	5		C
70		240			1		12	0.640	NA	d	256	NA	B
71	200	40		5	5		12	0.150		d	150-175		B
72	4.5			4.5	18	4.5	12	0.18		a			B
73	100	97			3	100	12	0.2	NA	a		2	B
74	10	40					4			a	125	10	B
75													B
76										a,d	80	20	B
77	60	50	140	0.5	10	10	12			a,d	237	15	B
78	20									a,d	20		B
79	160	60		5	5	60	12	0.1	8.2	c	320		B
80													B
81	80	80		10	2	50	12			a,b,c	50		B
82	160	120	10	8	2		4	0.2		a,d	170	2	B
83	10				10		12						B
84	10	40	20	5	2	58	7	0.154		a	8	10	B
85	10			2	2	1	12	0.11		c,e		10	C
86							12			d	10	71	E

LAND APPLICATION–Municipal

Ref. No.	Ground Cover (acres) and Annual Return				Crop	Acre	Return $	No. of Days/ Week Irrigated	Application Rates							
	Grass Acre Return	Forest Acre Return	Not Cultivated	No Vegetation					in./hr. Max.	in./hr. Avg.	in./day Max.	in./day Avg.	in./wk. Max.	in./wk. Avg.	in./yr. Max.	A
51																
52	22															
53	140	20	160													
54																
55	20															
56	65	30	10		Corn	20		3								
57					Alfalfa	5		3	0.25		1-1/5		2-0.25		40	
58		40														
59	400							5	2	1						
60																
61								1-1/2								
62	20							7								
63								7								
64	400							4			1.25		5			
65																
66	10	30		40				7			5		35			
67																
68								7								
69	30							7								
70					Hay	240		2								
71	150				Cotton	30		5								
72			x													
73								7			3					
74					Feed, Cotton	40		7								
75																
76																
77					Cotton	50		5								
78																
79			x					1			1					
80																
81	x							varies								
82					Cotton	72		varies								
83																
84	40				Farm	125	900	1								
					Grain	85										
85	5		10													
86																

LAND APPLICATION FACILITIES–Municipal

Ref. No.	Waste Applied By a) Spray (low press.) b) Spray (high press.) c) Tilling d) Overland flow e) Ridge and furrow f) Flooding	Renovated Water Collect (Yes) (No)	Cost Acre $	Year Purchased	Annual Cost Lease $	Term Lease (Year)	Value/Land 1972 Est. ($/acre)		Capital Improvements		
							Facility	Adj. Land	Cost $	Year Made	Cost (mgd)
51		N	500	1964			250	250			
52		N		1935				200			
53	a	N	458	1970-72							
54	a	N	225				250				
55		N	325	1968							
56	a	N		1890			400	400	34,000	1969	
57	a	N		1972							
58							1,800	1,800			
59	b,c	N									
60		N	200	1967					43,000	1967	
61	c	N	0	1963	0		400	400			
62	b	N									
63	b,c	N					700	400		1962	
64	a(2/3), b(1/3)		20	1928			200	200	75,000	1970	
65											
66	a,b	Y Chlorination supply Washdown water Sprinkler system	250				250	250			
67		Y					250	200			
68	b	Y									
69	a								None		
70	b	Y		1949-58							
71	a	Y	500	1948							
72		Y							NA		
73	a,c	Y	1958							1965	
74		N									
75											
76										1949	1
77	c	Y Pumped back to row irrigation									
78			300				500	600	4,000	1969-70	
79	c	N									
80			200	1953			500	700			
81	b,c	N				1					
82	a	N									
83			30	1919			175	160	10,000	1961	
84	b	N									
85											
86											

LAND APPLICATION FACILITIES–Municipal – Operation and Maintenance

Ref. No.	Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green Belt f) Other	Facility	Adj. Prop.	Distance to Nearest Residence (ft.)	Annual Budget $	Cap. (mgd)	Area (acre)	Treatment At Site a) Aeration b) Chlorination c) Other	Land Used For			Security Used a) Fenced b) Accessible to Public c) Patrolled d) Posted e) Other
									Farm	Graze	Other	
51	d	x	x	2,640								a
52	d		x	1,000				a				a,d
53	d		x	1,320		50	22	b				a,d
54				800	28,000	82	21	a,b				a
55							4.2					a,d
56	d	x		2,640	51,900		22	b				a,d
57	d	x	x	4,000		1.5	0.5		x			a
58												
59	c	x		2,000	47,000			b	x			a
	d		x									
60	b	x		5,280	14,500	20	6	a				a,b,c,d
61				6,000	3,000		24					a,d
62	d	x	x	3,381	45,062	33	14	a		x		a,d
63	d	x					3		x			a
64				1,000		6.2	48	a		x		a,d
65	None				12,000		27	None		x		a
66	a		x	1,000	27,000			a,b				a,b,c
67	a,d		x	1,000		23	8					a
68	d		x	500		12	10	a		x		a
69												
70				700								a,b
71	c,d	x	x	2,000			5		x	x		a,b,c,d
72	a	x		300	2,000		3					c
73	None			2,000	20,000		0.9			x		a
74	None			1,500			4		x			b,c
75					20,000		17	b	x			a
76												
77												
78												
79	a,d	x						a	x			a,d
80												
81	a,b,c	x			14,000		5			x		a
82	a,b,c		x	1,000				a	x			a
83	d	x		1,300		10		No	x	x		NA
84	d	x		3,000	20,000	2	5	a	x	x		a
85	a	x	x	1,350				b				a
86	a		x	300								

LAND APPLICATION FACILITIES–Municipal

	Operation and Maintenance					Monitoring Program			Effluent		
Ref. No.	Residence on Premises	Recreation Use Site	Public Health Restrict (Yes) (No)	Test Well No.	Test Well Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) VegAnalysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly y) Yearly o) Occasional	Are Under-drains Used (Yes) (No)	Re-used	Re-apply	Discharge to Receiving Water
51		No	No					N			
52	No	No	No			d,f		N			
53	No	No	Yes (Spraying & no swimming)	8	15-53			N			
54											
55				3	200	f	monthly	N			
56	No	No	Yes (Chlorination of effluent)	1	32	c,d,f	y			x	
57		No	Yes (Isolation from human use)					N			
58											
59	Yes	No	Yes (Secondary treatment)	None		c,d	3 x daily				
60	No	No	Yes (Weed spraying & insect control)	1	28			N			
61	No		No					N		x	
62	No	No	No	None		c,d	d	Y		x	
63		No	Yes (State)					N			
64	Yes										
65						d	2 months	N			
66	No	No	Yes (Chlorination standards)			c,d	2-7 wks	N			
67	No	No	No			c,d	2/wk.	N			
68		No	No			c,d,e	y				
69											
70	No	No	No					N			
71		Yes				c,d	monthly				
72		No	No		18	c		Y			
73		No						N			
74	No	No	No							x	
75		No	No					N			
76											
77											
78											
79	No	No						Y		x	
80											
81	No	Yes				None		N			
82	No	No	Yes (State)			None		N			
83		No	No	NA							
84	No	No	No	NA							
85	No	No	No			c,d	2 x wk.	Y			
86						None					

LAND APPLICATION FACILITIES–Municipal

	Effluent		Systems Performance								
				Future Plans				Information on Parameters Available			
								BOD mg/l		SS mg/l	
Ref. No.	Lost to Ground-water	Ground-water Inter-feres With Opera-tion (Yes) (No)	Data Available On a) Buildup/N b) " Heavy Metal c) " Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Qual. g) Deterioration Receiving Water Qual. h) Effect/Water Table i) Odors j) Health Hazards k) Other	Ex-pand	Con-tinue As Is	De-crease	Aban-don	To Land	Ground-water	To Land	Ground-water
51		N			x						
52		N	d,f		x			300	175	275	150
53		N		x							
54					x						
55		N			x						
56		N			x						
57		N	d	x							
58					x						
59		N	h,i,j								
60		N	i	x							
61		N									
62		Y (Excessive infiltration)	d,i,j	x				150	15		
63		N			x						
64					x						
65		N			x						
66		N	g	x	x			150	10	175	10
67			c	x				55	14	86	50
68				x							
69											
70					x						
71		N	a,d,c,f,g,h,i,j	x				26		48	
72		N				x					
73		N		x				170		169	
74		N		x							
75		N					x (Treatment plant to be built)		35		
76											
77											
78		N									
79		N	a,c,i		x						
80											
81		N		x							
82		N		x							
83	x		d,e	x							
84	x (Infiltration)			x							
85	x										
86							x (Compliance with state)				

LAND APPLICATION FACILITIES–Municipal – System Performance

Ref. No.	COD mg/l To Land	COD mg/l Ground-water	pH To Land	pH Ground-water	Fecal Coli/100 ml To Land	Fecal Coli/100 ml Ground-water	P mg/l To Land	P mg/l Ground-water	Total mg/l To Land	Total mg/l Ground-water	Nitrate mg/l To Land	Nitrate mg/l Ground-water	Nitrite mg/l To Land	Nitrite mg/l Ground-water	Cl mg/l To Land	Cl mg/l Ground-water
51																
52																
53			7.2		750											
54																
55																
56																
57																
58																
59																
60			x													
61						None								No		
62			8.5	8.5												
63																
64																
65																
66			7.7	7.6								3.0		1.5		
67			7.7	8.6												
68																
69						NA										
70														NA		
71																
72																
73			7.5													
74																
75																
76																
77																
78																
79																
80																
81							None							None		
82																
83																
84							NA									
85																
86																

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	Name, City and State	Wastewater Treatment a) None b) Screening c) Primary d) Secondary e) Tertiary f) Oxidation Ponds g) Effluent Chlorination	Average Flow (mgd)	Average BODs	PPM Suspended Solids	Maximum System Capacity (mgd)	% Domestic Waste
1	Beardmore, Div. of Can. Packers Acton, Ontario, Canada	b,c,d,e,f	1.000	400	250	2.000	Nil
2	Simpson Lee Paper Co. Redding, Ca.	c,d,f	9.600	15	70	12.500	0.5
3	Joan of Arc Co. (Princeville-Peoria) Il.	b,f	0.500	1,200	327		
4	Joan of Arc Co. (Hoopeston-Vermilion) Il.	b	0.200	2,000		0.500	
5	Green Giant Co. Belvidere, Il.	b	2.000	2,000	Varies	2.000	
6	Campbell Soup Co. Saratoga, In.		0.050	5	42	0.160	
7	Popejoy Poultry Logansport, In.	b	0.01/wk			0.016	
8	Weston Paper & Mfg. Co. Terre Haute, In.	a	0.200			0.200	
9	Albany Cheese, Inc. Grayson, Ky.	Other	25.000			50.000	None
10	Duffy-Mott Co., Inc. Hartford, Mi.	b	276.000			0.750	None
11	Simpson Lee Paper Co. Kalamazoo, Mi.	c	3.500	1,600	23	4.000	None
12	Green Giant Co. Blue Earth, Mn.	b	0.600	2,500	500	1.000	None
13	Green Giant Co. Cokato, Mn.	b	0.500	2,500	500	0.700	None
14	Green Giant Co. Winsted, Mn.	b	3.000	2,500	500	0.600	None
15	Borden Co., Comstock Foods Waterloo, N.Y.	b	0.170	4,600	5,000	0.290	100
16	H.P. Cannon & Son, Inc. Dunn, N.C.	b	180.000	1,000		250.000	
17	The Beckman & Gast Co. Mercer, Oh.	b	0.065	3,200	1,800	75,000.000	
18	Crown Zellerbach, Baltimore, Oh.	c,d,f	750.000	50-Sum. 250-Win.	100	1,400.000	

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	a) Canning (fruit) b) Canning (veg.) c) Milk d) Beverage (other) e) Pulp and Paper f) Inorganic g) Organic	Year Start	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused	Months Used	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other
1		1955	c	400	100	35	25	3	200	9	a,c,d,e
2	e	1964	c	100	28	60	1		11	12	d
3	b	1966		58.8							
4	b	1972	c	30	25	5				9	a
5	b	1949	c	270	160				110	12	d,e
6	b	1972	c	17	17		24		33	5	
7		1964	c	5	5					9	c,d
8	e	1961		200	100				100	12	
9	c	1961	c	22					14	12	a
10	a	1967	b,c		40	30	4			12	c,d,f
11	e	1971	c	240	80	400			240	12	a,d
12	b	1969	c	130	105				25	4	a,b,c
13	b	1960	b	130	90			40		2	a,b,c,d,e
14	c	1965	c		120	80		40		2	a,b,c
15	b	1968	c	140	84	16	30		10		c
16	b	1972	c	55	35	20	0	0	20	4	a
17	b	1957	b	24	24					4	c
18	e	1960	c	55	20	10	5	10	10	12	a,b

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	Depth to Ground-water Table (ft)	(%) Avg. Slope of Land	Ground Cover (acres) and Annual Return									No. of Days/ Week Irri-gated	Application Rates			
			Grass		Forest		Not Culti-vated	No Vege-tation					in./hr.		in./day	
			Acres	Return	Acres	Return			Crop	Acres	Return		Max.	Avg.	Max.	Avg.
1	Varies	5	120		5			10	Nil			7				
2	20	Level					x			12		6.5			2	
3			38									3			1.5	1
4	36	3	30									7	0.14	0.1		
5	6	0	x									7	0.6	0.6	0.65	0.65
6		2-3	17									5-7			0.45	0.25
7			5									3			0.44	0.38
8	0.2						200									
9		3	21									7	0.14		0.42	0.03
10	30	1	40									7	0.02	0.11	0.75	0.276
11	15								Alfalfa	60		7			9	7
									Corn	20						
12		2-3	105									7	0.22	0.22	1.8	0.15
13		4	90									7	0.5	0.5	0.3	0.2
14		17	80									7	0.5	0.5	0.32	0.16
15	3-10	1.3	140									7		0.37		0.19
16		2	55									6	1.5	0.5	1.5	0.5
17		20	24									7			0.1	0.1
18	24	5	45					10				7	0.1	0.1	2.8	2.0

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	Application Rates in./wk. Max.		in./yr. Max.		Waste Applied by d) Spray Irrigation e) Overland Flow f) Ridge & Furrow g) Other	Renovated Water Collect (Yes) (No)	Cost Acre	Year Purchased	Annual Cost Lease $	Term Lease (Year)	Value/Land 1972 Est. ($/acre) Facility	
	Max.	Avg.	Max.	Avg.							Facility	Adj. Land
1								1962			2,500	2,500
2			85		d	N	1,000	1963			1,500	2,000
3						N			54	25		
4					d	N						
5	4.5	4.5	60	60	d (summer) f (winter)	N	600	1960			5,000	2,000
6					d,e	N	533	1970			533	533
7	0.44	0.44			d	N						
8					d	N						
9	0.4	0.2	10	10	d	N	5,700	1961			800	800
10	5.25	1.93	86	86	d	N	600	1967-68			1,000	1,000
11					d	N	400	1960-72			350	350
12	3	1	20	15	d	N	600	1969			650	650
13	2	1.5	15	12	d	N			35	10	600	600
14	2.5	1.25	20	10	d	N			55	15	600	600
15		1.4			d	Y	550	1966-69	4,500	5	550	550
16	1.5	1.5				N		1972			1,800	
17					d	Y	750	1957-71			500	500
18	3.9	2.7	100	70	d	Y					600 1,200	600- 1,200

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	Capital Improvements Cost (Thous. of $)	Year Made	Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green belt Fac.	Adj. Pro.	Distance to Nearest Residence (Feet)	Annual Budget $	Holding Ponds Cap. (mgd)	Holding Ponds Area (acre)	Treatment at Site a) Aeration b) Chlorination c) Other	Land Used For Farm	Land Used For Graze	Land Used For Other
1	500	1971-72	c)x	x	250	120,000	100	25	a		No	
			a)	x								
			d)	x								
2	15	1964-71	a)	x	1,000	7,000			a			
			d)x	x								
3			d)x	x		5,000	200		a			
4	39	1972	d)x	x	2,500		7	9			No	
5	100	Varies	a)	x		40,000						
			c)	x								
			d)x	x								
6	34.8	1971	c)x		2,500	7,500	50	24				
			d)	x								
7			d)x	x	150		0			b		
8	25		c)x	x							No	
9	25	1961	a)	x	500	10,000			c (ozine)			x
			b)	x								
			c)	x								
			d)x	x								
10	100	1967-70	c)x									Grass
			d)	x	1,500	20,000	10	4	c (screening)			
11	40	1971	d)x	x	800	35,000	None			x		
12	150	1970	d)x	x		15,000			None			x
13			d)x	x	1,000	10,000	20		None			x
14	17	1965	d)x	x	1,000	5,000						x
15	500	1968-70	d)x	x	5,000	25,000	18		None			
16		1972	a)	x	500		None		None		x	
			b)	x								
			c)x									
			d)x	x								
17	500	1971			30	2,000	1	1.5				
18			c) x	x								
			b)	x								
			d)	x								

LAND APPLICATION FACILITIES
INDUSTRY

Ref. No.	Security Used a) Fenced b) Accessible to Public c) Patrolled d) Posted e) Other	Residence on Premises	Recreation Use-Site	Public Health Restrict (Yes) (No)	Test Wells No.	Test Wells Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly m) Monthly y) Yearly o) Occasion.	Underdrains Used (Yes) (No)	Re-used	Re-applied
1	a,c,d	No					c d e f	3/w 3/w 1/y 1/w	No		
2	a,d	Yes	No	No	None				No		
3	d	No	No				c	m	No		
4	a		No	No			c,f	w	No		
5		Yes			None				No		
6	b	No	No	Yes (Effluent standards SS & BOD)			d	w	No		
7	a	No	No	No					No		
8			No	No					No		
9	a,c,d	No							No	No	No
10	a	No			4		f	m	No		
11	a		No	No	16	6-45 ft	c,d e f g	d y m ea. cutting	No		
12		Yes			None				No		
13		Yes			None				No		
14		Yes			None				No		
15	a,e						c,d	1/w		No	No
16	b	No	No	No	None				No		
17	a	No	No	No					No		
18	a,d	No	No	No			c d e	1/m 2/y 3-10/y	Yes (Sent to aeration ponds)		

LAND APPLICATION FACILITIES
INDUSTRY

Data Available On
a) Buildup/N
b) " /Heavy Metal
c) " /Chlorides
d) Effect/Plants
e) Effect/Animals
f) Deterioration Groundwater Quality
g) Deterioration Receiving Water Quality
h) Effect/Water Table
i) Odors
j) Health Hazards
k) Other

Ref. No.	Effluent Discharged to Receiving Water	Effluent Groundwater Interferes with Operation (Yes) (No)	Data Available On	Future Plans Expand	Future Plans Continue As is	Future Plans Decrease	Future Plans Abandon	Information on Parameters Available BOD mg/1 To Land	Information on Parameters Available BOD mg/1 Groundwater
1			c,d,f,h,i					200	>5
2		No	d,e,g,i,j		x			30	
3									
4		Yes Reduces capacity			x			1,500	
5		No	a,b,d,e,f,g,h		x				
6		Yes		x					0-35
7		No	i,j		x				
8					x			Dry	11.3 R Solids
9		No	b,c,d,e,f,g,h,i,k		x				
10			f,g,h,i,j		x				
11		No	a,b,c,d,f,g,h,i,j,k	x				1,600 lbs per day	
12		No	b,c,d,e,f,g,h,i,k	x				2,500	
13		No	b,c,d,e,f,g,h,i,k		x				
14		No	b,c,d,e,f,g,h,i,k		x			2,500	
15		No	a,i		x			x	
16		No	No		x			1,000	
17		Yes	d,h		x	x Reusing water		3,200	
18		Yes Rainy periods	No		x			600	300

LAND APPLICATION FACILITIES
INDUSTRY
Information on Parameters Available

Ref. No.	SS mg/1 To Land	SS mg/1 Ground-water	COD mg/1 To Land	COD mg/1 Ground-water	Ph To Land	Ph Ground-water	Fecal Coli/100 ml To Land	Fecal Coli/100 ml Ground-water	P mg/l To Land	P mg/l Ground-water
1	3,000	1,500	600	>10	8.8-8.5	7.5		Nil	Trace	
2	1.7				6.5-810		25			
3										
4										
5										
6		10-50								
7										
8										
9										
10			2.3-7.9							
11	767 lbs per day		587 lbs per day		7.2		None		3.82 lbs per day	
12	500				6.5					
13										
14	500									
15	x				Yes					
16					8-9					
17					10-12					
18	120	55			8.1	7.8				

LAND APPLICATION FACILITIES
INDUSTRY

	Information on Parameters Available								
	Total N mg/1		Nitrate mg/1		Nitrite mg/1		CL mg/1		Climate
Ref. No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	Class (APWA)
1	High	Trace	Nil	Trace	Nil	Trace	3,000	1,500	E
2	350								A
3									D
4									D
5									D
6									D
7									D
8									D
9									D
10									E
11	125 lbs per day		28 lbs per day				1,725 lbs per day		
12									E
13									E
14									E
15									E
16									C
17									D
18									D

LAND APPLICATION FACILITIES—Industrial

Ref. No.	Name, City and State	Wastewater Treatment a) None b) Screening c) Primary d) Secondary e) Tertiary f) Oxidation Ponds g) Effluent Chlorination	Average Flow (mgd)	Average BODs	PPM Suspended Solids	Maximum System Capacity (mgd)	% Domestic Waste
19	Deeds Bros. Dairy, Inc. Lancaster, Oh.	a					
20	Libby, McNeill & Libby Liepsic, Oh.	b,d	0.666	452	1		
21	Sharp Canning, Inc. Rockford, Oh.	b,g	0.080	45	50	36,000.000	None
22	Campbell Soup Co. Paris, Tx.	b	3.100	550	350		None
23	Tooele City Corp. Tooele, Ut.	b,c,d	1.300	36			
24	Lamb-Weston Div. of Amfac. Connell, Wa.	b,c	1.630	1,500	5,000	2.100	None
25	Alto Coop Creamery Astico, Wi.	a				125,000.000	None
26	Cobb Canning Co. Cobb, Wi.	b	0.200	6,600	1,800	0.300	None
27	Frigo Cheese Corp. Wyocena, Wi.	a					
28	Green Giant Co. Fox Lake, Wi.	b	1.000	2,500	500	1.200	None
29	Green Giant Co. Ripon, Wi.	b	0.700	2,500	500	0.900	None
30	Green Giant Co. Rosendale, Wi.	b	1.000	2,500	500	1.200	None
31	Hoffman Corners Coop Creamery Kendall, Wi.	a					
32	Kansas City Star Co. Park Falls, Wi.	c,d	0.300	14,000- 24 hrs.			
33	Kimberley Clark Niagara, Wi.	a	1.320				
34	Loyal Canning Co. Loyal, Wi.	b	0.060	0.59	9		
35	Mammoth Spring Canning Oakfield, Wi.	b	0.459				
36	Oconomowoc Canning Co. Sun Prairie, Wi.	b	0.260	5,000	1,400	0.500	None

LAND APPLICATION FACILITIES – Industry

Ref. No.	a) Canning (fruit) b) Canning (veg.) c) Milk d) Beverage (other) e) Pulp and Paper f) Inorganic g) Organic	Year Start	Wastes to Disposal by a) Ditch b) Pipe (gravity) c) Pipe (pressure) d) Truck e) Rail f) Other	Used	Irrigation	Buffer	Onsite Storage	Onsite Treatment	Unused	Months Used	Soil Type a) Loam b) Silt c) Clay d) Sand e) Gravel f) Other
19	c		b	10	10						d
20	a	1971	c	215	130	20	10.3	10.3	55	8	c
21		1954		35	35	7				3(40)	c
22		1964	c	500	400				100	12	
23		1956	b	4					1	12	e
24	c	1969	c		265			3	95	12	d
25	c	1961	c	30.5				12.5	18	12	c
26	b	1960	c	40	22	18				4	a,b
27	c	1956	c	4					2.3	12	
28	b	1955	c	180	100				80	4	a,b,c,d
29	b	1955	c	80	80					4	a,d,e
30	b	1955	c	100	100					4	a,b,c,d
31	c		c	3	3					12	c
32	e	1952	c,d	202	122	60	40			7	b
33		1958	d	40	40					3	d,e
34	b	1950	c	46					17	3	a
35	b	1946	b	95	95	20	3.5		18	8	a,c
36	b	1953	c	127	89	6			32	4	a,d

LAND APPLICATION FACILITIES – Industry

Ref. No.	Depth to Ground-water Table (ft)	(%) Avg. Slope of Land	Ground Cover (acres) and Annual Return									No. of Days/Week Irrigated	Application Rates			
													in./hr.		in./day	
			Acres	Return	Acres	Return	Not Cultivated	No Vegetation	Crop	Acre	Return		Max.	Avg.	Max.	Avg.
19	30	0	45									7				
20	5 in.	0.5							Alfalfa	190		7	0.244	0.174	0.5	0.271
21	10	9	42									7				
22		2.5	500									43 wks/yr			0.5	0.25
23	400	3.0						x				20/ac				
24	600	1.5	265									7				
25			30.5													
26	35	2	40									6	0.7	0.035	2.7	0.4
27		0	4													
28		3	100									7	0.5	0.8	0.4	0.36
29			80									7	0.5	0.5	0.5	0.32
30		3	100									7	0.5	0.5	0.5	0.36
31	1.5	15	3													
32		0.3			200			2				6-7				
33	70-90	0.2														
34			46									None				
35		18	95									5-7	1		1	
36	24	0.3	89									6	0.7	0.023	3.0	0.32

LAND APPLICATION FACILITIES – Industry

Ref. No.	Application Rates in./wk. Max.	Avg.	in./yr. Max.	Avg.	Waste Applied by d) Spray Irrigation e) Overland Flow f) Ridge & Furrow g) Other	Renovated Water Collect (Yes) (No)	Cost Acre	Year Purchased	Annual Cost Lease $	Term Lease (Year)	Value Land 1972 Est. ($/acre) Facility	Adj. Land
19					d	N	2,000	1945			2,000	
20	3.5	1.9	100	27		Y		1971	17,000		1,000	1,000
21					d	N	500	1960			500	500
22			133	133	d	Y						
23					d	N					3,000	1,000
24			78	63	d	Y	225	1970			650	300
25					f	N	240	1959				
26	3.5	2.4	33	30	d	N			500	1	420	500
27					f	N						
28	3	2.6	40	36	d	N			50	10	500	500
29	3	2.3	40	32	d	N			35	10	600	600
30	3	2.5	36	25	d	N			40	10	600	1,000
31					f	N	300	1955				
32					d	N	35	1960			35	35
33						N		1955				
34					d	N		1926			200	200-500
35					d	N	225	1946			300	325
36	2.7	1.9	32	26	d				6,300	5	1,000	1,000

LAND APPLICATION FACILITIES–Industry

Ref. No.	Capital Improvements Cost (Thous. of $)	Capital Improvements Year Made	Zoning a) Residential b) Commercial c) Industrial d) Farm e) Green belt Fac.	Zoning Adj. Pro.	Distance to Nearest Residence (Feet)	Annual Budget $	Holding Ponds Cap. (mgd)	Holding Ponds Area (acre)	Treatment at Site a) Aeration b) Chlorination c) Other	Land Used For Farm	Land Used For Graze	Land Used For Other
19	8	1961	b)	x	3,960						x	
20	45	1972	d)	x	1,000	50,000	20	10.3	a	x		
21			d)x	x	400	150			b			
22			a)	x								
			d)	x								
23	700	1970-72	d)x		1,200					x		
24	210	1971	d)	x	5,300	179,300	40	18			x	
	50	1972										
25	17.01	1961										
26	8.5	1960	c)x		800	3,000					x	
			d)	x								
27					1,000							
28	60	Varies	d)x	x		15,000	20				x	
29	50	1955	d)x	x	1,000	12,000	5				x	
30	50	Varies	d)x	x	3,000	15,000	15				x	
31			d)x		1,500							
32	22	1956	d)	x	2,000							
33	110						0.06					
34			a)	x	40							x
			c)x									
			d)	x								
35	8.5	1972	d)x	x	1,600	14,000						
36	13	1953	c)x		2,000	5,200						
			d)	x								

LAND APPLICATION FACILITIES—Industry

Ref. No.	Security Used a) Fenced b) Accessible to Public c) Patrolled d) Posted e) Other	Residence on Premises	Recreation Use-Site	Public Health Restrict (Yes) (No)	Test Wells No. Depth	Test for a) Influent b) Effluent c) Soil Analysis d) Groundwater Analysis e) Veg. Analysis f) Animal/Insect g) Other	Frequency d) Daily w) Weekly m) Monthly y) Yearly o) Occasion.	Are Underdrains Used (Yes) (No)	Reused	Reapplied
19	a		No	Yes	None	f	1/y	No		
20	a,c,d	Yes	No	Yes	None	c,d	w			Yes
				(odor and		e	y			
				runoff)		f	w			
						g	3/y			
21	b	No	No	No				No		
22	a	No				d	d	No		
23	a,d	No								Yes
24	a,d	No	No	No	None	c,d	1/d		No	Yes
						e	10/y			
25										
26	a	No							No	
27										
28		Yes							No	
29	a	No							No	
30		No							No	
31	a	No								Yes
32		No	No	No				No		
33					5			No		
34			Yes							
35	d							No		
36	a	Yes								

LAND APPLICATION FACILITIES – Industry

	Effluent			Future Plans				Information on Parameters Available BOD mg/l	
Ref. No.	Discharged to Receiving Water	Groundwater Interferes with Operation (Yes) (No)	Data Available On a) Buildup/N b) " /Heavy Metal c) " /Chlorides d) Effect/Plants e) Effect/Animals f) Deterioration Groundwater Quality g) Deterioration Receiving Water Quality h) Effect/Water Table i) Odors j) Health Hazards k) Other	Expand	Continue As is	Decrease	Abandon	To Land	Groundwater
19		No	No	x				542	9.7
20		No	d,g,h,i,j	x					
21			No		x			435	2.5
22				x					
23	No	No						900	700
24		No	a,e,i	x					
25									
26			b,c,d,e,f,g,h,i,k		x				
27								2,500	
28			d		x			2,500	
29			d,e		x			2,500	
30			b,c,d,e,f,g,h,i,k		x	None			
31		No						12,500	
32		No							
33		No			x				
34		Yes	b,c,d,e,f,g,h,i,k		x				
35			No		x				
36			b,c,d,e,f,g,h,i,k		x				

LAND APPLICATION FACILITIES – Industry

	Information on Parameters Available									
	SS mg/l		COD mg/l		Ph		Fecal Coli/100 ml		P mg/l	
Ref. No.	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water	To Land	Ground-water
19	None								None	
20	445	67.3 VSS=0			6.15	7.0				
21										
22	192	6	751	62	5.5	7.2			8.5	3.7
23										
24	0.43				7-11		0		10-50	
25										
26										
27										
28	500									
29	500									
30	500									
31										
32			15,100		2.4					
33										
34										
35										
36										

LAND APPLICATION FACILITIES – Industry

Ref. No.	Total N mg/l To Land	Total N mg/l Ground-water	Nitrate mg/l To Land	Nitrate mg/l Ground-water	Nitrite mg/l To Land	Nitrite mg/l Ground-water	CL mg/l To Land	CL mg/l Ground-water	Climate Class (APWA)
	Information on Parameters Available								
19									D
20	5.02	0							D
21									D
22	15.8	2.0	0.09	0.08	0.05	0.05	45	31	C
23									B
24									D
25									E
26									E
27									E
28									E
29									E
30									E
31									E
32									E
33									E
34									E
35									E
36									E

APPENDIX E

LAND APPLICATION FACILITIES VERIFIED BUT NOT SURVEYED
(Summary of Responses to Preliminary Screening)

Ref. No.	City/Agency	State	Date Began	Flow Rate MGD	Flow % Dom.	Flow % Ind.	Method of Application a) Flood b) Spray c) R & F d) Other
1	Simpson Lee Paper Co., Anderson	Ca.	10/64		0.5	99.5	a,b
2	Armona Sanitary District	Ca.	1952	0.3	X	X	d
3	City of Arroyo Grande	Ca.	1924	0.4	X		a,d
4	Big Bear Lake San. Dist.	Ca.		0.06	100		d
5	Capistrano Beach San. Dist.	Ca.	1959	0.6	95	5	d
6	City of Ceres	Ca.	1935	0.65	90	10	d
7	City of Chino	Ca.		2.2	X		
8	City of Coachella	Ca.	1938	1.1			a
9	City of Corona	Ca.	1948	3.0	93	7	c,d
10	Encinitas San. Dist.	Ca.	1953	0.43	100		b,c
11	City of Fowler	Ca.	1950	0.25	X		a
12	Hunt-Wesson Foods, Inc., Fullerton	Ca.	7/71	4.0			b
13	City of Gilroy	Ca.	1927	2	33	67	a,d
14	City of Gustine	Ca.	1930	3.5			a
15	Eastern Mun. Wat. Dist., Hemet	Ca.	1965	1.715	100		d
16	City of Hollister	Ca.	7/72	5.0		100	d
17	Hughson San. Dist.	Ca.	1948	1.5	30	70	a
18	Ivanhoe Pub. Util. Dist.	Ca.	1953	0.30	100		a,c
19	Lamont Pub. Util. Dist.	Ca.	1965	0.9	95	5	d
20	Laton Co. Water Dist., Laton	Ca.	1/61		100		a
21	City of Lemoore	Ca.	1910	1	50	50	a,c
22	City of Lindsay	Ca.	9/71	0.8		100	a
23	City of Live Oak	Ca.	1953	0.95			a,d
24	Olivehurst Pub. Util. Dist.	Ca.	6/56	0.75	99.5	0.5	a
25	City of Orange Cove	Ca.	1956	2.88	90	10	a,c
26	City of Orland	Ca.	8/64	1.75	100		d
27	City of Oroville	Ca.		1.5			
28	City of Palm Springs	Ca.			100		d
29	City of Perris	Ca.	1947	0.6	98		a,d
30	Enterprise Pub. Util. Dist. Redding	Ca.	7/73	1.0	100		b
31	City of Redlands	Ca.	1963	2.5	90	10	a,d
32	City of Rialto	Ca.	9/57	0.6	100		b
33	Ridgecrest San. Dist.	Ca.	1954	1.0	100		a,c
34	Rio Linda Co. Water Dist.	Ca.	1955	0.4	100		a
35	Riverdale Pub. Util. Dist.	Ca.	1958		100		a,c,d
36	Co. of San Diego, Pub. Wks. Dept. of San. of Fl. Con.	Ca.	6/61	0.1	100		d
37	Lakeside San. Dist., San Diego	Ca.	1962	1.2	100		d

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Ref. No.	City/Agency	State	Date Began	Flow Rate MGD	Flow %		Method of Application a) Flood b) Spray c) R & F d) Other
					Dom	Ind.	
38	City of Sanger	Ca.	1967	3.0	100	100	c
39	San Marcos Co. Water Dist.	Ca.	1963	0.5	90	10	b
40	City of Selma	Ca.		1	X	X	a
41	N. Tahoe Pub. Util. Dist., Tahoe Vista	Ca.	1952	0.75	X		a,b,c
42	City of Tehachapi	Ca.	1938	0.6	100		b
43	Tranquility Pub. Util. Dist.	Ca.	1952	0.1	95	5	a
44	Tuolumne Co. Water Dist. No. 1 Twain Harte	Ca.	7/65	0.18	100		b,c
45	Montalvo Mun. Imp. Dist., Ventura	Ca.	1970	0.1	92	8	a
46	Moorpark Co. San. Dist., Ventura	Ca.		0.4	100		d
47	Victorville San. Dist.	Ca.	1924	0.7	99		d
48	Wasco Pub. Util. Dist.	Ca.	1937	0.83	95	5	a,c
49	Yreka	Ca.	9/53	0.7	100		c
50	Cherokee Products Co., Haddock	Ga.	6/70	0.5		100	b
51	Lion Counry Safari, Stockbridge	Ga.	7/72	0.055	100		b
52	Glenn-More Home, Inc., Thomasville	Ga.	9/71	0.0075	100		b
53	Lowndes Co. Bd. of Comm , Valdosta	Ga.	7/72	0.035	100		b
54	J. R. Simplot Co., Boise	Id.	7/72	3.0		100	a,c
55	J. R. Simplot Co., Caldwell	Id.		7.5	60-70	30-40	a
56	Stokely-Van Camp, Emmett	Id.		0.5		100	b
57	Rogers Bros., Idaho Falls	Id.		1.07		X	b,c
58	Idaho Fresh Pak, Lewisville	Id.		1.06		100	a
59	American Fine Foods, Inc., Payette	Id.		0.5		100	a
60	County Line Cheese Co., Auburn	Ind.	1958	0.05		X	b,c
61	Graham Cheese Corp., Elnora	Ind.	1960			X	c
62	Pure Sealed Dairy, Inc., Ft.Wayne	Ind.	1960	0.09		X	b
63	Holland Dairies, Inc., Holland	Ind.	1967	60		100	b
64	Morgan Packing Co., Inc., Warren	Ind.	8/25	0.1		100	b,c
65	Armour Food Co., DPO Div., Springfield	Ky.	Before 1940	0.25		100	b
66	Vahlsing, Inc., Easton	Me.	1967	1	1	99	b
67	J. Richard Phillips, Jr. & Sons,Inc.,Berlin	Md.	1953	0.9		100	b
68	Walter T. Andrews & Son,Inc.,Cambridge	Md.	7/69	0.12		100	b
69	A.W. Feeser Div., Westminster	Md.	8/72	2		X	d
70	City of Belding	Mich.	6/72	0.2	60 (storm 30)	10	b
71	Village of Vermontville	Mich.	10/72	0.36	98	2	a
72	Watervliet Paper Co. Div. of Hammermill Paper	Mich.	9/72	1		100	b
73	Olivia Canning Co., Olivia	Minn.	8/66			100	b
74	City of Lockwood	Mo.	1971		100		b,d
75	Lander Co. Sewer & Water Dist. Battle Mountain	Nev.	1969	0.23	100		d

Ref. No.	City/Agency	State	Date Began	Flow Rate MGD	Flow %		Method of Application a) Flood b) Spray c) R & F d) Other
					Dom.	Ind.	
76	City of Concord, N.H.	N.H.	1973	4.2			d
77	N.H. Water Supply & Pollution Control Comm., Concord	N.H.	6/71		100		b
78	Hunt Ritter San. System, Bridgeton	N.J.	1961	2.2		100	b
79	M&M/Mars, Hackettstown	N.J.	1959	0.21		100	b
80	Seabrook Farms Co., Inc., Seabrook	N.J.	1946	4.4	9	90	b
81	Los Alamos Co. Utilities	N.M.	1950	0.361	100		b
82	City of Raton	N.M.	1950	0.4	90	10	a,c
83	Town of Silver City	N.M.	1965	0.5	100		b
84	Campbell Soup Co., Napoleon	Oh.	1954	5		100	b
85	City of Napoleon	Oh.	10/65	4.5	45	55	d
86	Howard Paper Mills, Inc., Urbana	Oh.	1965	0.66		100	b
87	City of Hollis	Okla.	1964	0.322	100		a,c
88	Lamb-Weston, Inc., Weston	Ore.	1964	0.685		100	b
89	General Foods Corp., Woodburn	Ore.	1963	2.4		100	b
90	H.J. Heinz Co., Chambersburg	Pa.	Mid 50's	0.2-0.9		100	b,d
91	Knouse Foods Co-op, Inc. Peach Glen	Pa.	1965	0.172		100	b
92	Masonite Corp., Towanda	Pa.	1966	0.450		100	b
93	Kraft Foods Div., Kraftco Corp. Alexandria	Tenn.	1949	0.0079		100	b
94	City of Anson	Tex.	1952	0.4	100		a,b,c
95	City of Azle, Water & Sewer	Tex.	1962	0.25	100		d
96	City of Coleman	Tex.		0.35	100		a,c
97	City of Crane	Tex.		0.2	100		a,c
98	City of Crosbyton	Tex.	1966	0.125	90	10	c
99	City of Devine	Tex.	2/69	0.25	100		a,b,c
100	City of Eldorado	Tex.	1945	1	100		a
101	Freer Water Control & Imp. Dist.	Tex.	1/62	0.25	100		a,b
102	City of Friona	Tex.	3/62	Less than 1	X		a
103	Armour Food Co., Fresh Meats Div. Hereford	Tex.	1970	1.15	1	99	c
104	City of Hondo	Tex.	1/69	0.4	100		a
105	City of McLean	Tex.	1927	0.1	100		a,d
106	City of Odessa, Plant No. 1	Tex	1948	1.075			a
	Plant No. 2			0.28			
107	Crockett Co. WC&ID No. 1, Ozona	Tex.	1950	0.3		100	a,c
108	City of Petersburg	Tex.		0.2		X	a,c
109	City of Quitague	Tex.	1928	0.06	100		b
110	City of Rotan	Tex.	1936	0.11	80	20	a
111	City of Sabinal	Tex			X		
112	City of Santa Ana	Tex.	1967		X		b
113	City of Seminole	Tex.	1940	0.9	X		a,c

Ref. No.	City/Agency	State	Date Began	Flow Rate MGD	Flow % Dom	Flow % Ind.	Method of Application a) Flood b) Spray c) R & F d) Other
114	City of Slaton	Tex.	1966	0.37	98	2	c
115	City of Sonora	Tex.	5/63	0.3	90		a,c
116	City of Stanton	Tex.	1926	12	X		a
117	City of Stratford	Tex.	6/68	0.01	100		a
118	City of Sundown	Tex.	5/50	0.16	75		a,c,d
119	City of Sweetwater	Tex.	1958	0.75	70	30	a,c
120	Lakehaven Sewer Dist., Federal Way	Wash.	1960				d
	Plant No. 1			1.3			
	Plant No. 2			0.9			
121	City of Othello, Redmond	Wash.		2		100	d
122	Lake Hills Sewer Dist., Redmond	Wash.	1955	2		95	b
123	Dept. of Pub. Wks., Yakima	Wash.	1958	2.0		100	b
124	Baker Canning Co., Antigo	Wis.		0.4		X	b
125	Dairy Maid Co-op, Augusta	Wis.	6/56	0.2			c
126	Country Gardens, Inc., Gillett	Wis.		0.2		100	b
127	Hillside Dairy, Cadott	Wis.	1956			100	c
128	John Wuetrich Creamery Co., Greenwood	Wis.	1904	0.06		100	d
129	Stokely-Van Camp, Inc., Horicon	Wis.	6/72	0.12		100	b
130	City of Milton	Wis.	1939	0.4	100		a
131	Mindoro Co-op Creamery, Mindoro	Wis.	1954	0.03		100	a,c
132	Flambeau Paper Co., Park Falls	Wis.	1952	0.1		1	b
133	Shiocton Kraut Co., Inc., Shiocton	Wis.	1962	0.009		X	b
134	Garden Valley Co-op Creamery, Waumandee	Wis.	1955	0.012			c
135	Waunakee Canning Co., Waunakee	Wis.	1925	0.43			b
136	Westby Elec.,Water,Util., Westby	Wis.	1958	0.174	X		a,c

APPENDIX F

DEPARTMENT OF DEFENSE INSTALLATIONS – LAND APPLICATION OF SEWAGE TREATMENT PLANT EFFLUENT AT ARMY AND NAVY INSTALLATIONS

Army Installations

Post	Type Application	Remarks
1. Fort Devens, Massachusetts	Rapid infiltration. 100 percent of effluent from Imhoff tanks.	In operation for approximately 30 years - 22 sand beds, very satisfactory operation.
2. Hunter-Liggett Military Reservation Jolon, California	Aerated lagoons, spray irrigation <100,000 gpd.	New facility replaces evaporation ponds. Flow presently insufficient to require use of spray irrigation.
3. Fort Huachuca, Arizona	Two plants - secondary spray irrigation. Approximately 1.5 mgd.	During growing season, all effluent is sprayed on golf course and Chaffee Drill Field.
4. Fort Carson, Colorado	Spray irrigation with part of flow - secondary treatment.	During growing season, approximately 1.2 mgd of 1.8 mgd flow is sprayed on golf course.
5. Fitzsimmons Army Hospital Denver, Colorado	Spray irrigation with part of flow - secondary treatment.	Irrigate golf course approximately 0.5 mgd.
6. Fort Irwin Barstow, California	Evaporation and spray irrigation of secondary effluent.	All of the effluent from 5 oxidation lagoons is evaporated or used to irrigate the golf course. One mgd capacity. Post capacity down currently.
7. Safeguard Grand Forks, North Dakota	Spray irrigation.	Project in AE&D. Design includes 310 acre/feet of stabilization ponds, grass or grain crops, 0.3 mgd. Flow will include cooler blowdown water.

Navy Installations

Base	Type Application	Remarks
1. Camp Pendleton, California	Spray irrigation and ground recharge.	Effluent from 6 secondary treatment plants flows to oxidation ponds. Approximately 2/3 mgd sprayed nightly on golf course. Approximately 0.9 mgd discharged to percolation basin. This is a mixture of discharge from a raw waste water stabilization pond and treated effluent from the oxidation ponds.

Air Force Installations

Base	Type Application	Remarks
1. Eglin AFB, Florida	Spray irrigation of secondary effluent on Auxiliary Area 9.	Present system is being remodeled to permit disposal of all flow by spray irrigation. Construction scheduled for completion July 1973. Total flow approximately 4 mgd.
2. George AFB, California	Spray irrigation of secondary effluent on golf course for water conservation.	1-1/2 mgd. No discharge to surface water course from holding lagoons - all to land.
3. Scott AFB, Illinois	Spray irrigation.	0.5 to 1 mgd. Includes irrigation of golf course.
4. Tyndall AFB, Florida	Spray irrigation.	1 mgd capacity. In design. Construction scheduled to begin end of fiscal year 1973.
5. Air Force Academy, Colorado	Spray irrigation. Applied to golf course, athletic fields, medians.	Effluent from secondary treatment plant is discharged to a series of four lakes to which well water is added. No. 2 lake is aerated. Postwide irrigation from these lakes. Estimated 2 mgd.

Source: U. S. Army Crops of Engineers

APPENDIX G

MEDICAL DEPARTMENT CRITERIA FOR LAND DISPOSAL OF DOMESTIC EFFLUENTS

Department of the Army, Surgeon General
Issued September 27, 1972

1. Included herein are recommended criteria for four techniques of land disposal: spray irrigation, rapid infiltration, overland runoff, and evaporation ponds. These criteria represent the judgment of sanitary engineers, microbiologists and geologists, based on information contained in the following technical publications.

a. US Army Medical Environmental Engineering Research Unit Report No. 73-02, subject: *Problem Definition Study: Evaluation of Health and Hygiene Aspects of Land Disposal of Wastewater at Military Installations, August 1972.*

b. Pennsylvania State University Publication 23, subject: *Wastewater Renovation and Conservation, 1967.*

c. DA, Corps of Engineers Wastewater Management Report 72-1, subject: *Assessment of the Effectiveness and Effects of Land Disposal Methodologies of Wastewater Management, January 1972.*

d. Cold Regions Research and Engineering Laboratory Special Report 171, subject: *Wastewater Management by Disposal on the Land, May 1972.*

2. Criteria common to all:

a. Pretreatment

(1) Criterion: Provide secondary (biological) treatment to all wastes prior to application or ponding.
Rationale: The literature indicates that hydraulic loading rate is the principal limiting factor in determining the assimilative capacity of a soil; the literature consistently indicates that neither BOD nor suspended solids concentrations in the applied waste have a limiting effect - provided that application is intermittent allowing for the re-aeration of the upper layers of the soil mass. However, the provision of secondary treatment is important not for BOD or suspended solids reduction, but for the following: first, biological degradation of putrescible materials, with a consequent reduction in the potential for the development of nuisance conditions; and second, removal of a high percentage of pathogens from the waste stream with a concomitant reduction in the medical risk to operating personnel.

(2) Criterion: Provide post-chlorination with rapid mixing such that 0.5 mg/l residual chlorine (total) remains after a 15-minute contact period.
Rationale: The maximum destruction of pathogenic organisms prior to application or ponding is warranted; post-chlorination further reduces the potential for groundwater contamination; post-chlorination adds a further element of protection for on-site operation and maintenance personnel.

b. Access Limitation

Criterion: Assure limited access to holding facilities, application sites, and ponds.
Rationale: The risk of contact contamination should be minimized by providing fencing or other suitable barriers to prevent general access by civilian and military personnel. The use of wastewaters for the irrigation of recreation areas, however, is an exception, but is subject to the constraints outlined in paragraph 3a(2), below.

c. Nonpotable Identification

Criterion: Provide readily identifiable

nonpotable notices, markings or codings for all conveyance facilities and appurtenances.

Rationale: The risk of accidental ingestion by the general public of wastewater from disposal appurtenances in recreation areas must be recognized. In addition, the inadvertent cross-connection of pressurized waste conveyance facilities to the potable water system by facilities personnel must be anticipated and prevented by coding or marking schemes.

d. Vector Control

Criterion: Control vector populations incident to spraying and ponding operations.

Rationale: Increased vector breeding can be anticipated as a result of land disposal operations. In the cases of spray irrigation and overland runoff operations, incidental ponding should be minimized at the disposal site. In all holding and ponding operations, seasonal fluctuations in vector populations should be controlled through the judicious application of organophosphate pesticides as required.

e. Surveillance

(1) Criterion: Provide surveillance to protect all local water sources. As a minimum this should include quarterly analyses for fecal coliform, and annual analyses for the indicator constituents: total dissolved solids, surfactants (MBAS), nitrates, and sodium. Sample stations should encompass existing wells used for potable water sources including, as appropriate, private wells of local residents.

Rationale: The principal risk associated with land disposal operations is the biological and chemical contamination of local water supplies. The surveillance program should be structured to provide prompt warning in the event of such contamination.

(2) Criterion: Provide surveillance sufficient to prevent chemical contamination of the receiving aquifer. As a minimum this should include quarterly analyses for total dissolved solids, sodium, nitrate, and surfactants (MBAS). Sample stations in the form of small observation wells should be positioned both on-site and down-gradient on the aquifer.

Rationale: One major problem associated with land disposal operations is the elevation of total dissolved solids, nitrate and sodium concentrations in the receiving aquifer. If such constituents rise to unacceptable concentrations undetected, no corrective action is possible; the water supplies down-gradient could, consequently, be compromised for years, even if further waste applications were halted. The objective, therefore, is to detect increases in concentration with sufficient frequency to allow reevaluation of project feasibility in time to guarantee the continuous availability of the aquifer as a water resource. Another potential problem with land disposal is the short-circuiting of water flow within the reactive soil mass; analyses for surfactants has been recommended to provide early detection.

3. Criteria applicable to spray irrigation:

a. Control of Aerosols

(1) General Application. Criteria provided in this paragraph pertain to tracts of land used solely for disposal purposes.

(a) Criterion: Design spray equipment to minimize aerosol formation at the disposal site.

Rationale: A number of factors affect the potential for pathogen transport through increased aerosol formation at the appurtenances themselves. Higher discharge pressures yield a reduction in droplet size and a consequent increase in the potential for aerosol formation; discharge pressures in the range 5-50 psi are consequently recommended. The height of of the spray appurtenances has a bearing on aerosol formation; the minimum height, compatible with local vegetation, should be employed. Similarly, consideration should be given to the shape of the spray cone itself in the selection of equipment.

(b) Criterion: Provide a downwind buffer zone between the disposal site and high density populations such as residential areas and schools.

Rationale: The indeterminate nature of travel distances associated with windborne aerosols warrants care in site selection. Minimum transport distances are associated with spray operations in forest land where downwind buffer zones on the order of 200 feet are considered adequate; greater transport distances are associated with open sites. The buffer zone could take one of several forms: space could be maintained between the disposal site and the population of concern; windbreaks could be positioned between the site and the population; or the spray disposal site itself could be positioned within natural terrain features that minimize wind effects.

(c) Criterion: Restrict spraying as much as possible to periods of daylight at sites where the use of a buffer zone to protect high density populations is impractical.

Rationale: During daylight hours, thelower humidity and the higher incidence of ultraviolet radiation combine to minimize the potential for long distance conveyance of viable airborne pathogens.

(d) Criterion: Cease spraying operations during periods of high wind velocity at sites where the use of a buffer zone to protect high density populations is impractical.

Rationale: Small increases in wind velocity significantly increase the transport distances of aerosols. For each 3 mph increase in wind velocity, transport distances increase on the order of 100 feet.

(2) Recreation Land Application. Criteria provided in this paragraph pertain to tracts of land used both for disposal purposes and for recreational use, e.g., golf courses, parade fields, athletic fields.

(a) Criterion: Provide post-chlorination with rapid mixing, such that 2.0 mg/l residual chlorine (total) remains at the point of spray application.

Rationale: The application of sewage effluent to recreation lands requires greater protection for the general public; the increase in protection is manifested in the maintenance of a chlorine residual. The presence of such a residual further reduces the potential for the contact contamination of the using public and the potential for the contamination of residential areas normally located in close proximity to such areas.

(b) Criterion: Restrict spraying as much as possible to the hours of darkness.

Rationale: The high use of recreation facilities during the daytime hours precludes the spraying of sewage at that time. The maintenance of the elevated chlorine residual discussed above should offset higher humidity and lower ultraviolet radiation, typical of the night, factors which encourage the viability of pathogens.

b. Protection of Water Resources

(1) Criterion: Locate the sites on relatively flat (<15°) upland terrain, the optimum slope being 2-6 degrees.
Rationale: Relatively flat terrain minimizes the potential for erosion, surface runoff contamination to streams, and excessive pumping heads. Upland area is stipulated to avoid valley bottoms subject to flooding and removal of dormant pathogenic organisms in the topsoil. A gentle slope will permit efficient removal of water from lateral piping immediately upon cessation of spray-irrigation activity in a specific area.

(2) Criterion: Assure the presence of a soil having a large reactive surface area plus an adequate sustained percolation rate of at least 0.25 inches/hour and sufficient aeration capacity. Such conditions can generally be achieved in silt-textured soils with a small percentage (3-6%) of clay but sufficiently high in organic matter to have a well-aggregated structure.
Rationale: The recommended percolation rate reflects sufficient soil porosity to accommodate the optimum spray application rate and avoid surface ponding; a greater percolation capacity would allow the concurrent accommodation of precipitation with spray irrigation. Aggregated soil structure is necessary to preclude development of an anaerobic environment within the soil horizon. With the above two considerations in mind, a maximum amount of soil-reactive surface should be provided to effect efficient renovation of the effluent.

(3) Criterion: Provide a soil depth of at least seven feet, together with an additional minimum depth of eight feet to the water table through soil, parent material, and/or bedrock.
Rationale: The stated minimum soil column will allow complete, or almost complete, biological and chemical renovation of the sewage effluent. The additional required depth to the groundwater table should accommodate seasonal fluctuations in water table elevation and permit further assimilation of the more mobile effluent constituents, thus preventing groundwater contamination.

(4) Criterion: Assure that bedrock (or unconsolidated sediments, as the case may be) is sufficiently porous or permeable to convey the increased volume of applied water to the water table, and thence, away from the site. Avoid, however, siting over zones of excessive permeability (transport >100 ft/day), e.g., fault zones, fracture trace intersections, open bedding planes, sinkholes, and other solution openings.
Rationale: The bedrock must have sufficient vertical and lateral water transport capacities to avoid continual elevation of the water table and possible eventual soil saturation conditions, as could develop over perched water tables or thick shale units. On the other hand, retention time must be adequate to preclude the possibility for short-circuiting by the principal contaminants, so common especially in areas of limestone bedrock.

(5) Criterion: Provide a vegetative mat of forest, crops, or grasses.
Rationale: Vegetation and ground litter prevent soil clogging, ponding, runoff, and erosion, and provide some insulation for soil and piping from icing conditions. The maintenance of a vegetative mat may

be impractical in semi-arid climates typical of of the southwestern United States, in that rapid evaporation can cause "up-leached" toxic salt concentrations near the surface which could kill the plant life.

(6) Criterion: Utilize, at each individual site, a spray application rate of 0.25 inch/hour for eight continuous hours. Allow one week between applications at each site. Choose the number of sites used and the area of each site based on the operational time schedule and the design quantity of effluent.
Rationale: For spray irrigation of secondary effluent, hydraulic load, not effluent composition, is critical; the stated application rate is optimum. This rate is in consonance with the soil percolation capacity and allows for a one-week period of drying for maintenance of an aerobic environment within the soil. The number of sites required is determined by multiplying the number of 8-hour periods of daily operation by the number of days of operation per week. Continuous (24-hour) operation requires 21 plots and is desirable because it accommodates continuous effluent production and distribution and also keeps water flowing in the main pipes continuously which tends to prevent freezing.

(7) Criterion: Assure that no streams or municipal/industrial wells are located within the sites selected.
Rationale: Drawdown from an immediate well would tend to minimize retention time and to increase the potential for well contamination. Direct spraying onto a stream or runoff and erosion during intense rainstorms would cause immediate contamination of surface water.

4. Criteria applicable to rapid infiltration ponds:

a. Criterion: provide dike or mound structure protection along site perimeter; avoid siting on valley floodplain.
Rationale: The site must be protected from flushing by extraneous overland flow or flood waters to prevent overflow and resulting surface water contamination.

b. Criterion: Provide a thick pond bed composed of a course-grained soil capable of sustaining a percolation rate of 1-1/2 to 2 inches/hour.
Rationale: The optimum efficient application rate dictates a percolation rate as stated to prevent surface overflow which, in turn, necessitates a coarse-grained soil of limited reactive surface. Accordingly, several hundred feet of vertical or lateral intergranular flow are required to effect chemical and biological renovation of the effluent.

c. Criterion: Utilize an effluent criteria stated in paragraph 3b(4) above are met.

d. Criterion: Utilize an effluent application rate of approximately 1 foot/day for 10 to 14 days, with an intervening drying period on the order of two weeks between applications.
Rationale: This rate is in consonance with the soil percolation capacity and permits a period of drying in order to effect oxidation of organic matter and maintenance of rapid infiltration.

e. Criterion: Insure that no active wells are located in the proximity of the site.
Rationale: Drawdown from an immediate well would tend to accelerate percolation of effluent into the groundwater, causing a greater potential for well contamination.

5. Criteria applicable to overland runoff:

a. Criterion: Assure that the criteria stated in paragraph 3b(1) and 3b(4) are met.

b. Criterion: Utilize a fine-grained soil (high clay content) which has a sustained percolation capacity of less than 0.2

inch/day.

Rationale: Since the objective is effluent renovation at the soil *surface*, infiltration, leading to potential groundwater contamination, must be minimized.

c. Criterion: Provide a site consisting of trenches spaced approximately 100 feet apart per percent slope (from 2-6%) and having a continuous vegetative mat.

Rationale: The stated design, gradient, and vegetation requirements will allow adequate effluent-soil contact time and vegetative filtration of BOD and suspended solids to achieve chemical and biological renovation prior to discharge into a surface water channel.

6. Criteria applicable to evaporation ponds:

a. Criterion: Assure that the criterion stated in paragraph 3b(1) is met.

b. Criterion: Provide the evaporation ponds with impervious beds and banks.

Rationale: Leakage must be nonexistent or minimal to prevent groundwater contamination. If significant leakage cannot be prevented, all criteria listed in paragraphs 3b(3)and (3b(4) must be met.

c. Criterion: Assure that the evaporation-precipitation ratio is sufficiently high to permit efficient operation.

Rationale: Evaporation must exceed both precipitation and effluent application to preclude overflow and resulting surface water contamination.

APPENDIX H
CLIMATIC CLASSIFICATION

One of the main functions of the application of wastewater effluents to land areas is to enhance agricultural and silvicultural growths where these liquids are used for this purpose. Thus, effective management of water resources by this alternative method is subject to the common constraints imposed by climatic conditions on farm operations.

Irrigation by any of the means used to apply wastewater to the land is a means of "modifying weather" by varying and augmenting the amount of precipitation which falls on farm areas. Decision on the applicability and feasibility of land application must be reached after consideration of the climate conditions which will be imposed on farm operations and, conversely, of the effects of exposure of large bodies of water to the atmosphere, in the form of airborne particles and aerosol mists, and land-based bodies of water.

Climatic classifications for agricultural purposes are different from any such categorizations of regions and weather for other purposes, such as human comfort, the nurturing of fish and wildlife and the balancing of the water ecology of the environment. The climatic classifications in the coterminous United States used in this report have been designated with these factors in mind. They are related to seasonal length, temperatures, humidity, rainfall, solar heat, length of day, sun's ray angles, cloud cover, groundwater tables and other related phenomena of climate.

The feasibility of adopting land application methods as alternatives for so-called conventional treatment and disposal of wastewater effluents into surface water sources must be judged on the basis of these climatic conditions. Included in this broad decision-making problem is understanding of soil microbial activity and its ability to metabolize wastes substances retained by the soil by absorption or physical retention in soil interstices, and the energy impacts of evapotranspiration phenomena.

An appreciable percentage of wastewaters applied to land areas never penetrates the depth of the soil cover and percolates into water-bearing aquifers. During high-temperature periods, when ambient temperatures average above 75°F, more than 0.2 inch of water per day can be evapotranspired from the surface of the soil or vegetative growths. The annual loss of water can range from 40 inches in warm Southern regions, to less than 25 inches in cooler, wetter areas such as the Northwestern region. Other climatic factors affecting land application systems include freezing periods, storm intensities and durations, relative humidity and dew points. The five zones designated in this study take all of these conditions into consideration.

Climate is a two-way phenomenon. The relationship between agricultural pursuits and climate is obvious. Less understood are the effects of wastewater application to land areas and the management of holding basins and lagoon acreages on the climate. The inference might be made that these effects could be adverse. The transfer of moisture from land and vegetative surfaces to the atmosphere might have a definitive influence on climate. Studies reported by Dr. J. R. Mather, C. W. Thornthwaite and others have explored the meteorological effects of such water transfers and the amounts of this transition from surface water resources into transient moisture in the unending water cycle of precipitation-evaporation-condensation--reprecipitation. The reference contained below, taken from material prepared by Dr. Mather, indicates the scope of such geologic-hydrologic investigations of the "reverse" impact of land application concepts on an otherwise stable water and climate cycle.

These studies and bibliographic references make clear the fact that land application is not a simple-faceted task of placing "spent waters" onto land which can utilize them for enhancement of the agricultural climate. Researchers who are specialists in the multidisciplinary phases of this subject have investigated such novel aspects as the effects of reservoirs on climate due to warming and cooling effects, and the stabilizing of diurnal temperature ranges and relative humidities; the effect of large-scale irrigation with "new" water or wastewaters; the effect of evaporation from irrigating sprays; the climatic influences of cooling towers; and the effects of large lake areas on regional and local precipitation.

Dr. Mather drew the conclusion from such studies that "... climatic changes that accompany irrigation enterprises are relatively local in magnitude. Air moving over an irrigated tract will rapidly pick up moisture. Within the first few hundred feet in all but the most arid regions, the air will have essentially reached equilibrium. Once the air has left the moistened area, turbulent mixing will rapidly reduce the moisture content to its original low value. The relatively small, local influence of wetted areas (land application areas) suggests that large land treatment systems or other schemes to modify nature through the creation of many large watered tracts, shelter belts, or reservoirs will be relatively ineffective except in the immediate vicinity of the wetted surface."

This reassuring evaluation of this little-understood and equally inadequately considered facet of land application systems removes any implied threat that the maximization of land application management systems for handling vast millions of gallons of wastewaters on a national scale, as an alternative to conventional wastes treatment and disposal practices, will have any lasting or widespread effect on the climate of the United States, other than local modifications of weather patterns.

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Appendix I

BACKGROUND PAPERS ON LAND APPLICATION OF MUNICIPAL EFFLUENTS

A. EXPERIENCES WITH LAND SPREADING OF MUNICIPAL EFFLUENTS[1]

by

Richard E. Thomas and Curtis C. Harlin, Jr.[2]

Introduction

The U.S. Environmental Protection Agency (EPA) is a very young agency which was created in December 1970. Although the agency is less than two years old, its experiences with land spreading of municipal effluents extend over more than 15 years. This longer period of experiences stems from the efforts of our predecessor agencies which include the Federal Water Quality Administration, the Federal Water Pollution Control Administration, and the U.S. Public Health Service. These past efforts were conducted as a result of the Federal Water Pollution Control Act of 1956 and subsequent amendments of this Act.

Within the current organization of EPA, the National Water Quality Control Research Program located at the Robert S. Kerr Water Research Center, Ada, Oklahoma, is actively participating in research to improve our understanding of the processes which influence and limit the performance of land-based wastewater management systems. The primary goal of this research is to advance the state of the art so that sound technology will serve as a base for reliable design of systems to achieve desirable and specific levels of performance.

Our evaluation of the current state of the art leads us to conclude that there are several distinctly different approaches to the spreading of municipal effluents on the land which show promise for further development and widespread use. It is convenient to group these land spreading approaches into three categories which we refer to as (1) infiltration-percolation, (2) cropland irrigation, and (3) spray-runoff. We use this grouping because each of these approaches has well-defined differences regarding land area requirements and the resulting interactions with the plant, soil, and water components of localized ecosystems.

The infiltration-percolation group includes systems frequently referred to as recharge basins, ridge-and-furrow basins, or flooding basins. Systems of this type are operated on the basis that the applied wastewater moves downward through the soil for treatment. Coarse textured soils are preferred in order to achieve the desired areal loadings which range up to 400 feet per year under ideal conditions.

The chief functions of plants are the relatively minor roles of shading the surface of the soil and helping to stabilize good physical conditions in the soil. Physical, chemical, and biochemical interactions in the soil are the major processes contributing to treatment of the applied wastewater. Surface runoff is prohibited; evaporative losses are relatively minor; and substantially all of the renovated water becomes groundwater.

Crop irrigation is an immediate and direct reuse of a municipal effluent for beneficial production of crops not for direct human consumption. Common broad irrigation or spray irrigation techniques are used to apply the effluent to crops at normal irrigation rates or somewhat in excess of these rates. Land area requirements are large because areal loadings are one to two inches per week with total growing season applications of less than 8 feet per year. Plants play a prominent role in the removal of plant nutrients such as nitrogen and phosphorus. Physical, chemical, and biochemical interactions in the soil are less dominant in achieving desired performance because of the relatively low rate of areal loading. Surface-runoff may or may not be controlled; evapotranspiration losses may be equal to or greater than the amount of water moving through the soil to become groundwater. This large percentage of evaporative losses can result in a substantial

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[1] Presented at the First Annual Institute of Food and Agricultural Sciences (IFAS) Workshop on Land Renovation of Waste Water in Florida, May 31-June 1, 1972, Tampa, Florida.

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increase in the total salt content of the water percolating down through the soils.

The spray-runoff is especially suited to use with impermeable soils and falls intermediate between the infiltration-percolation approach and the crop irrigation approach in land area requirements. Vegetative cover is necessary to stabilize the carefully prepared runoff slopes and terraces, but the harvesting of a crop is secondary to the objective of treating the applied effluent. The physical, chemical, and biochemical processes take place as the liquid moves slowly over the surface of the soil by sheet flow. More than half of the applied effluent is returned directly to surface waters as planned and controlled runoff of the renovated water. The remainder of the water is either lost through evaporative processes or percolates down through the soil to become groundwater. A comparison of selected characteristics of the three land-spreading systems is presented in Table 1.

Now, let us consider some research studies which have been conducted or financially supported by EPA or its predecessor agencies. Discussions of the results of these studies will provide additional detail about system designs and management techniques which can be utilized to achieve specified treatment or reuse objectives. The three categories of land spreading will be discussed in the same sequence in which they have been described in preceding paragraphs.

Infiltration-Percolation Systems

Infiltration-percolation approaches such as septic tank-soil absorption systems, ridge and furrow basins, and flooding basins have been utilized for many decades as a convenient disposal practice. Design and operation of these systems have emphasized the disposal concept, and it is only within the last decade that an effort has been made to emphasize the treatment capability of the infiltration-percolation approach. EPA and its predecessors have been involved in six research projects having the objective of utilizing the infiltration-percolation approach to treat municipal effluents for subsequent reuse. Four of these studies were conducted in the water-short southwestern states and two were conducted in water-rich north central states.

First, let us consider the objectives and results of the four studies conducted in the water-short southwestern states. A study at Whittier Narrows, California was conducted to study the effectiveness of the infiltration-approach for direct recharge of a potable groundwater supply with secondary effluent.[1] The results of this study showed that spreading periods of about 9 hours followed by drying periods of about 15 hours produced a clear and highly oxidized water acceptable for recharge at this site. This method of operation resulted in conversion of almost all applied nitrogen to nitrate and produced nitrate concentrations in the renovated water two to three times more than acceptable limits for drinking water. Due to the high nitrate concentration, it was recommended that dilution with low nitrate water would be necessary before repumping for use as a water supply.

A concurrent study at Santee, California evaluated the use of infiltration-percolation to make municipal effluent suitable to fill and maintain the water level in recreational lakes[2]. Locating the infiltration-percolation basins in the alluvium of a shallow stream channel provided substantial lateral movement underground after about 10 feet of vertical percolation. In addition to excellent removal of solids, oxygen-demanding substances, pathogens, and phosphorus, total nitrogen in the renovated water was reduced to 1.5 mg/l (from 25 mg/l applied to spreading basins) after about 1,500 feet of lateral underground travel. Emphasis was placed on evaluating this nitrogen removal at a Phoenix, Arizona study using a similar mode of operation.[3] Results of the Phoenix study showed that the frequency of application has a major influence on nitrogen removal. Spreading and drying periods of a few days or less promoted nitrification and resulted in less than 10 percent total nitrogen removal whereas spreading and drying periods of 10 to 20 days resulted in apparent denitrification and up to 80 percent nitrogen removal. This study also highlighted the importance of

TABLE 1
COMPARATIVE CHARACTISTICS OF SYSTEMS

	Type of System		
Factor	**Crop Irrigation**	**Spray-Runoff**	**Infiltration-Percolation**
Application Rate	2-8 ft. per year	8-15 ft. per year	15-400 ft. per year
Land required for 1 mgd flow (3.1 ac. ft.)	140-560 acres plus buffer zones	75-140 acres plus buffer zones	3-75 acres plus buffer zones
Application techniques	Spray or flood	Spray	Usually flood
Soils	Moderately permeable soils with good productivity when irrigated	Slowly permeable soils such as clay loams and clay	Rapidly permeable soils such as sands, loamy sands, and sandy loams
Probability of influencing groundwater quality	Moderate	Slight	Certain
Needed depth to groundwater	About 5 ft.	Not known	About 15 ft.
Fate of wastewater	Predominately evaporation or deep percolation	Surface discharge dominates over evaporation and percolation	Percolation to groundwater

underground residence time and/or distance of travel for achieving phosphorus removal at the high loadings used for the infiltration-percolation approach.

Another important factor related to local hydrological conditions was graphically demonstrated by a study at Hemet, California.[4] An unusually wet winter season at this location caused the local water table to rise up to the bottom of the spreading basins. The resultant reduction in hydraulic acceptance rate and deterioration of treatment efficiency made it necessary to quickly develop an alternate method for handling their effluent.

Now let us look at the results of the two infiltration-percolation studies in the cool and semi-humid climate of the north central states. One of these entailed a four-year experiment using 20-hour spraying periods followed by 4-hour drying periods to apply about 98 feet per year of effluent on a sandy soil.[5] Our definitions place this system in the infiltration-percolation category even though it uses spray application and is referred to as a spray irrigation system. It is significant that the use of short spreading and drying cycles in this climate produced nitrogen and phosphorus interactions comparable to those for studies in the Southwest. Nitrogen was converted to nitrate which appeared in the groundwater (at a concentration comparable to that in a municipal effluent) while 70 percent of the phosphorus was removed after no more than 20 feet of travel distance through the soil. The other study in this climate was a one-year evaluation of the performance of an existing ridge and furrow basin.[6] The system was located on a silt loam soil and a loading of about 45 feet per year was obtained with wetting periods of two weeks followed by drying periods of two weeks. As was the case for the study in Arizona, the long spreading period resulted in about 70 percent removal of total nitrogen without affecting the removal capacity for other measured parameters.

Our experiences with the use of the infiltration-percolation approach to land spreading of municipal effluents are encouraging for future use on a much larger scale. Technological data are already available to design and operate systems for a limited number of situations, but of more importance is the apparent utility of the approach under widely differing climatic conditions. We are optimistic that further research efforts can establish well-defined design criteria and management techniques for use throughout the United States.

Cropland Irrigation Systems

Cropland irrigation with municipal effluents is a well-established practice in the southwestern United States and has been practiced continuously for over 50 years at many municipalities. This practice has developed to satisfy a need for more water as well as a need to manage municipal effluents in an acceptable manner. Utilization of the practice has grown steadily since the first operations were initiated around 1900, and there are over 300 active operations at present. In spite of this impressive number of operating installations, there has been little research conducted to establish a technological base for predicting the long-term influence of various management techniques on the crops, the soils, the groundwater, or the overall ecology of the area of influence. EPA is initiating several projects to assess the current state of our knowledge and to improve management of cropland irrigation systems.

One group of projects is directed to locating and evaluating currently available quantitative information on application rates, crop responses, soil changes, and groundwater quality changes from systems which have been operating for varying periods of time. This effort should be very useful in defining management techniques for general use in the Southwest as well as furnishing a base on which to build for other geographic locations.

Another group of projects is oriented toward field development of management techniques for the cooler and more humid regions east of the Mississippi River. One of these projects has been in operation at Pennsylvania State University since 1963.[7]

The results of this project over the first seven years of operation have shown that cropland irrigation can be practiced in a cool and semi-humid climate in a manner that will promote crop production while contributing substantial recharge to the groundwater. Results reported to date from the Pennsylvania State University project indicate that an application rate of 2 inches per week over a 30-week growing season (a total application of 60 inches per year) is the most beneficial for general use under conditions existing at this site. The other field development projects are the Muskegon County Wastewater Management System currently under construction at Muskegon, Michigan, and a smaller but similar project just initiated at Belding, Michigan. It will be several years before field data from these projects will be available for reliable interpretation and subsequent use in establishing improved management practices.

Our experience with the cropland irrigation approach to land spreading stems largely from qualitative information on the performance of existing systems concentrated in the semi-arid Southwest. In general, the performance of these systems has been judged to be satisfactory; yet there is a general lack of quantitative data to substantiate this judgment. A carefully managed experimental system located at Pennsylvania State University has produced quantitative information over a 7-year period which indicates that cropland irrigation with municipal effluent can be a practicable wastewater management technique in cool and semi-humid climates.

Spray-Runoff Systems

The spray-runoff approach has not been utilized for treatment of municipal wastewaters, but it has been employed at many industrial plants. Experiences at some of these industrial plants indicated that spray-runoff had considerable potential for treatment of any wastewater containing biodegradable organics.

In 1967, our research group at the Robert S. Kerr Water Research Center initiated a cooperative study with the Campbell Soup Company to conduct a one-year research study at their Paris, Texas plant. The objective of the study was to evaluate the performance of the spray-runoff system at this location which had been in operation for 5 years. The results of the study on this 3 mgd capacity system showed that the spray-runoff approach was indeed a very efficient system for removal of suspended solids, oxygen-demanding substances, and nitrogen from the cannery wastewater produced at this plant.[8] The results of this investigation encouraged us to explore the capability of the spray-runoff approach for other wastewaters in which biodegradable organics were the major source of pollutants to be removed by a treatment process. We are currently conducting in-house research to develop the spray-runoff approach for treatment of raw domestic sewage and for runoff from beef cattle feedlots. Preliminary results for both of these wastewaters are very encouraging for development of practicable systems. For example, the experimental spray-runoff system we have designed for the treatment of raw comminuted domestic sewage is producing an effluent that is of tertiary treatment quality without producing any sludge to handle. The spray-runoff system designed for treatment of the runoff collected from beef cattle feedlots has produced equally encouraging performance data. A technical report covering five months of field evaluation data for the feedlot runoff system will be available soon.

Technology to utilize the spray-runoff approach for management of domestic wastewaters is in the rudimentary stage of development. The exploratory research which we have in progress indicates that spray-runoff treatment of raw domestic wastewater is feasible but many more questions must be answered before the process can be developed for general use.

Summary

The foregoing is a brief summary of the EPA's involvement in land spreading of municipal effluents for treatment and/or reuse. Coverage of the many research projects introduced has, by choice, been limited and selective in order to highlight the objectives of this presentation. Further information about many of the projects has been reported in readily available technical publications in addition to those cited in this paper. For those projects currently in progress at the Robert S. Kerr Water Research Center of the EPA, the authors can be contacted to obtain further information.

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B. FATE OF MATERIALS APPLIED[1]

by

Richard E. Thomas[2]

When wastewaters are applied to the land, a substantial quantity of suspended and dissolved solids is deposited on the land. The fate of these materials is an important factor to consider in the selection of a land-based alternative for management of wastewaters. There are four repositories which may receive and store appreciable fractions of the materials applied to the land at a wastewater management site: (1) Some of the material may be volatilized and released to the atmosphere; (2) another fraction of the material may be released directly to surface waters with runoff; (3) particulates and some dissolved material will be temporarily or permanently retained in the soil; and (4) the remainder of the material will be leached down through the soil to be stored in the groundwater. The distribution of materials among these four repositories is dependent on physical, chemical and biochemical interactions which take place in the soil. These interactions in the soil are influenced by many factors related to the characteristics of the wastewater and to characteristics of specific land treatment sites. Some of these factors are beyond the control of man while others can be managed to control the fate of applied materials.

The purpose of this presentation is to describe several management approaches which can be used to influence the fate of materials applied to land treatment sites. The materials to be included will be grouped into three units for convenience. The units will be designated as suspended materials, major plant nutrients, and other constituents. Within each unit, the fate of materials will be discussed in relation to three approaches to land treatment of wastewaters. These approaches to land treatment are based on hydrological behavior and can be described briefly as follows: (l) Infiltration systems which are operated at relatively high hydraulic rates and emphasize groundwater recharge as the fate of the applied wastewater; (2) irrigation systems which are operated at relatively low hydraulic rates and emphasize both groundwater recharge and evaporative losses as the fate of the applied wastewater; and (3) spray-runoff systems which are operated at intermediate hydraulic rates and emphasize runoff to surface waters as the fate of the applied wastewater.

Suspended Materials

Suspended materials in a wastewater settle out quickly or are filtered out as the applied wastewater percolates through the soil. The results of numerous studies can be cited to show essentially complete retention of suspended materials in the soil after relatively short travel distances of a few inches to a few feet depending on the texture of the soil. Obviously continued retention and storage of suspended solids in the soil pores would lead to clogging of the soil pores and a sharp reduction in the permeability of the soil. This phenomenon has been studied extensively and researchers have identified many factors influencing the clogging of soil pores. Articles by McGauhey and Krone,[1] Thomas, Schwartz, and Bendixen [2] or Thomas and Law[3] are good reference sources to obtain a more complete understanding of the clogging process. Fortunately, a major fraction of the suspended solids are volatile and are biochemically oxidized to products which prevent clogging of the soil pores. In fact, the biochemical oxygen demand exerted by this biodegradable fraction of the suspended material is a key factor in determining the successful operation of many

[1] Presented at the Conference on Land Disposal of Wastewaters, Michigan State University, Kellogg Center, East Lansing, Michigan, Dec. 6-7, 1972.

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land treatment systems and hence the fate of all materials applied to the system.

Information from practical experiences with land disposal of wastewaters shows a wide divergence in the amount of biodegradable solids which can be applied to the soil without inducing conditions that cause soil clogging and the undesirable effects which accompany soil clogging. Blosser and Caron[4] recommend biochemical oxygen demand (BOD) loadings of up to 200 lbs./acre/day for disposal of pulp and paper mill effluents. Thomas and Bendixen[5] report that sewage sludge loadings equivalent to 170 lbs./acre/day of organic carbon can be applied to sandy soils for extended periods of operation. Bouwer[6] reports a BOD loading of 45 lbs./acre/day for secondary sewage effluent. Parizek et al,[7] report BOD loadings of less than 2 lbs./acre/day for irrigation with secondary effluent. An important point to consider is covered by Thomas and Bendixen[5] in their discussion of the degradation of sewage organics in soil. They cite several references which indicate that organic carbon additions of as much as 25 lbs./acre/day are needed to maintain a static organic matter content in the soil. Such additions help to maintain the tilth of a soil and would not be expected to pose problems of soil clogging. With this concept in mind, one can make useful projections about the fate of suspended materials applied to the soil through the three approaches to land treatment.

Typical suspended solids concentrations found in secondary effluents should have little effect on the operation of well designed and well managed wastewater-irrigation systems. We can illustrate this by assuming an effluent with 50 mg/l of suspended solids (of which 70 percent are biodegradable) and an irrigation rate of 2 inches per week. Such a system would result in a total suspended solids loading of 3 lbs./acre/day and biodegradable suspended solids loading of 2 lbs./acre/day. The BOD exerted by the biodegradable fraction of these solids is substantially less than the 25 lbs./acre/day of organic additions required to maintain a static organic matter content in soils. The residual of the nonbiodegradable fraction of the suspended materials also represents a small contribution to the total volume of affected soil. An acre-inch of a mineral soil weighs about 300,000 lbs. while the 1 lb./acre/day of nonbiodegradable suspended solids amounts to an addition of only 365 lbs./acre/year. It would be more than a decade before the added residue amounted to one percent of the weight of the surface inch of soil and many decades before the residue amounted to one percent of the soil normally mixed by plowing. From this illustration, it is clear that the suspended solids added to the soil through wastewater irrigation at irrigation rates of less than eight feet per year do not pose a problem of soil clogging. The fate of much of the suspended solids is biooxidation to gases, water, and minerals. The fate of the nonbiodegradable fraction is accumulation in the soil, but the quantity which may accumulate represents a very minor addition to the total soil volume. Qualitative information from numerous wastewater irrigation operations bears out the fact that suspended solids do not pose specific operational problems, and the results of research investigations such as the 14-year study by Day, Stroehlein, and Tucker[8] show that irrigation with activated sludge effluent did not alter soil organic matter content relative to irrigation with well water.

Suspended solids added to the soil by the infiltration approach have a major influence on system operation and performance because hydraulic loading rates can range up to 300 feet per year. The high loading rates characteristically used for infiltration systems greatly increase the potential for soil clogging to interfere with the successful operation of a system. The same theoretical composition of effluent we used to illustrate the irrigation approach will clearly demonstrate this increased potential for soil clogging. With our suspended solids content of 50 mg/l (70 percent biodegradable) and a hydraulic loading of 120 feet per year (an intermediate value), the total suspended solids load is 45 lbs./acre/day. This load exceeds the organic addition needed to maintain a static organic matter content in many soils. The BOD exerted by this amount of biodegradable material can exceed that available in the soil environment and lead to severe clogging of soil pores. This phenomenon of soil clogging is well documented, and many research studies on this subject were reviewed by McGauhey and Krone.[1] The importance of available oxygen for prevention of clogging is discussed by Thomas, Schwartz, and Bendixen.[2] Intermittent dosing and drying periods are effective for avoiding the problem of soil clogging and assuring that the fate of suspended materials is biooxidation to gases, water and minerals. Successful operation of infiltration systems for decades at many locations throughout the United States provides qualitative support on the fate of suspended solids, but quantitative data are unavailable or meager for most of these installations. Quantitative information available from the results of research studies does verify that the fate of suspended solids is biooxidation with accumulation of some residue in the surface soil. Research conducted by Bouwer at Phoenix, Arizona, resulted in excellent suspended solids removals with a BOD loading of 45 lbs./acre/day at a hydraulic loading of 300 feet per year with an activated sludge effluent. Studies by Larson at Detroit Lakes, Minnesota[10] indicated successful operation with a BOD loading of 23 lbs./acre/day at a hydraulic loading of 95 feet per year with secondary effluent.

Suspended solids added to the soil through the spray-runoff approach pose a different situation for removal. The liquid does not percolate downward through the soil, and the filtering capability of the soil is not involved in the removal of the suspended materials. The principal mechanism of removal is still biooxidation, but the biooxidation must be accomplished as the liquid moves slowly across the surface of the soil. There is no problem of potential soil clogging, but the suspended solids still have a major influence on system operation through the BOD which they exert. The successful operation of spray-runoff systems is dependent on maintaining an oxygen level in the soil which sustains biooxidation of organic materials applied to the soil. Since maintenance of biooxidative conditions is a prerequisite for successful operation of a system, the fate of biodegradable suspended solids is oxidation to gases, water, and minerals. The use of the spray-runoff approach for land treatment of wastewaters has been limited, and there are only a few examples to substantiate the fate of suspended solids added to the soil by the spray-runoff approach. Law Thomas, and Myers[11] reported 94 percent reduction in suspended solids concentrations at a loading of 20 lbs./acre/day of suspended solids (48 lbs./acre/day of BOD for a spray-runoff system treating cannery wastewater applied at the rate of 0.36 inches per day. Kirby[12] reports that the grass filtration system at Melbourne, Australia, achieves 96 percent removal of suspended solids at a loading of 34 lbs./acre/day of suspended solids (68 lbs./acre/day of BOD) with raw domestic sewage applied at the rate of 0.75 inches per day. The spray-runoff approach to land treatment does not achieve the virtually complete removal of suspended materials achieved by the irrigation approach and the infiltration approach because some material usually remains in suspension and is carried in the runoff from the treatment plots.

Major Plant Nutrients

The major plant nutrients which are of particular concern at this time are nitrogen and phosphorus. Each of these nutrients enter into many interactions within the plant-soil complex. Dr. Erickson has covered the mechanisms of these interactions in a companion paper, and I shall limit my discussion to the fate of these nutrients for practical utilization of the three approaches to land treatment of wastewaters.

Typical nitrogen and phosphorus concentrations in secondary effluents are such that crop uptake plays an important role in the fate of these nutrients for the wastewater irrigation approach. Turning once again to our theoretical effluent, we can add characteristic concentrations of 20 mg/l for nitrogen and 10 mg/l phosphorus to illustrate the fate of these nutrients. With our irrigation rate of 2 inches per week and applications during a projected growing period of 30 weeks, the nitrogen loading would be 270 lbs./acre and the phosphorus loading would be 135 lbs./acre. A 25 ton/acre yield of ensilage corn is one example of many crops which could utilize essentially all of the 270 lbs./acre of nitrogen applied to the soil. This removal of nitrogen by crop uptake is essential to the irrigation approach because excess nitrogen is converted to the mobile nitrate ion which is carried into the groundwater by soil percolate. Our 25 ton/acre yield of ensilage corn would remove approximately 30 lbs. of the 135 lbs./acre of phosphorus added to the soil in the applied wastewater. As discussed by Dr. Erickson, the phosphorus in excess of that removed by the crop is not readily leached from the soil. In fact, many soils have the capacity to retain thousands of pounds of phosphorus within the soil profile while the leachate from the soil contains only a trace of phosphorus. This capability of the soil to retain and fix phosphorus is as important to the removal of phosphorus as crop uptake is to the removal of nitrogen since phosphorus applications exceed potential crop uptake by a substantial margin. The experimental study at Pennsylvania State University[7] is a good example of nitrogen removal by crop uptake and phosphorus removal by retention in the soil. Of particular local interest is the work of Ellis and Erickson[13] on the phosphorus retention of many Michigan soils.

The high application rates used for the infiltration approach negate the influence of crops as a factor in the fate of major nutrients. Applying the 20 mg/l of nitrogen and 10 mg/l of phosphorus of our theoretical effluent to the 120 feet per year hydraulic loading for the infiltration approach produces a nitrogen loading of about 6,500 lbs./acre/year and a phosphorus loading of about 3,300 lbs./acre/year. Crop uptake can account for little of these totals, and crop removal is not a significant factor in the fate of major plant nutrients for the infiltration approach to land treatment. The fate of nitrogen applied by the infiltration approach is largely dependent on nitrogen removal by microbial denitrification of the nitrogen to gaseous nitrogen with release to the atmosphere. Management techniques to promote this process are in the early stages of development, and much of the applied nitrogen can be expected to appear in the underdrainage or groundwater in the nitrate form. Management techniques to promote denitrification were studied by Bouwer,[6] and he achieved up to 80 percent removal of the 21,000 lbs./acre/year of nitrogen applied to the soil. The operational procedures followed by Larson[10] promoted microbial nitrification rather than denitrification, and nitrate nitrogen concentration in the groundwater rose to 31 mg/l. Phosphorus removal for the infiltration approach is achieved by retention in the soil through the mechanisms described by Dr. Erickson in his companion paper. Finer textured soils have the best capability to retain phosphorus, but coarse textured soils suitable for the infiltration approach can also achieve excellent phosphorus removal. The process of phosphorus removal is also less dependent on specific management techniques. Continuing with the same research studies we find that Bouwer[6] reported about 95 percent removal of the 21,000 lbs./acre/year of phosphorus applied with his management techniques after about 200 feet of lateral movement through the soil while Larson[10] reported 75 percent removal of the 2,400 lbs./acre/year applied with his management techniques after about 10 feet of vertical movement through the soil. These examples serve to indicate that infiltration systems can be managed so that retention in the soil is the fate of the applied phosphorus.

The application rates used for the spray-runoff approach also reduce the importance of crop uptake as a factor in determining the fate of nitrogen and phosphorus. With the projected concentrations of 20 mg/l for nitrogen and 10 mg/l for phosphorus in our theoretical effluent and a hydraulic load of 0.4 inches per day (comparable to rates reported by Kirby,[12] and Law, Thomas, and Myers[11] the nitrogen loading would be 650 lbs./acre/year and the phosphorus loading would be 325 lbs./acre/year. Crop uptake of 250 lbs. per acre of nitrogen and 30 lbs. per acre of phosphorus are appreciable, but they leave the major fraction of the nutrients for a fate other than crop removal. The major mechanism for nitrogen removal in the spray-runoff mode of operaton is by denitrification. An environment which promotes denitrification must be achieved by adjusting the hydraulic load and hence the BOD load to maintain a low dissolved oxygen level which is favorable for denitrification. Kirby[12] reports 60 percent removal of total nitrogen from raw sewage applied at a rate of 0.8 inches per day but does not indicate the nitrogen balance. Law, Thomas, and Myers[11] reported 90 percent mass removal of nitrogen from cannery wastewater with a nitrogen loading of 515 lbs./acre/year. Phosphorus removal by the spray-runoff mode of operation is relatively inefficient with present operating procedures. The processes which retain phosphorus in the soil cannot be brought into play as the liquid moves over the surface of the soil. A substantial fraction of the phosphorus applied in the spray-runoff mode of operation will be carried in the runoff unless special steps are taken to improve the removal of phosphorus. Kirby[12] reports 35 percent removal of phosphorus for spray-runoff treatment of raw sewage applied at 0.8 inches per day. Law, Thomas, and Myers report two levels of phosphorus removal for cannery wastewater with a phosphorus loading of 224 lbs./acre/year. Daily applications of wastewater applied over a 6 to 8-hour period of spraying resulted in phosphorus removals of about 55 percent or 120 lbs./acre/year, while the same amount of total application put on with 12-hour spray periods three times per week resulted in phosphorus removals of 88 percent which would amount to 180 lbs./acre/year of the 224 lbs./acre/year applied to the soil.

Other Constituents

Treated wastewaters contain a host of other constituents in widely varying amounts including substantial quantities of soluble salts such as sodium chloride and minor amounts of trace constituents such as heavy metals and pesticides. This grouping of other constituents is a highly variable component depending on the source of the original water supply and the sources contributing to the final composition of the wastewater during collection. In addition to the variability due to source, individual constituents may undergo many different interactions in the plant-soil environment. Fragmentary information is available about the fate of many specific constituents of interest, but much remains to be learned about the behavior and hence the fate of trace constituents added to the soil through the various approaches of land treatment for wastewater management. Although it is impractical to make many generalizations based on the fragmentary information currently available, there are some readily predictable results associated with the three approaches to land treatment for management of wastewaters.

The fate of soluble salts or total dissolved solids applied to the land is usually surface waters through runoff or groundwater through percolating soil water. The soil has little capacity to retain most soluble salts commonly found in treated wastewaters, and the only mechanism for appreciable accumulation of total dissolved salts in the soil is a lack of sufficient percolating water to leach the salts from the soil. Since the primary fate of total dissolved solids is the effluent from the land treatment system or the "renovated wastewater," it is important to remember the fate of the water applied to the land through the irrigation, infiltration, and spray-runoff approaches to land treatment. The loadings of 2- to 8-feet per year for the crop irrigation approach are such that the balance between evapotranspiration and rainfall can substantially influence the fate of the applied water and the concentration of total dissolved salts in the water percolating downward through the soil. An excess of evapotranspiration over rainfall reduces the amount of water percolating downward but increases the concentration of dissolved solids in the percolate. If the excess of evapotranspiration over rainfall is great enough, the fate of some of the dissolved solids will be an accumulation in the soil. An excess of rainfall over evapotranspiration increases the amount of water percolating downward through the soil and decreases the concentration of dissolved solids in the percolate. The high loadings employed for the infiltration approach nullify the effects of evapotranspiration or rainfall on the concentration of dissolved solids in the underdrainage. For example, the projected loading of 120 feet per year which has been used to illustrate the fate of suspended solids and major plant nutrients would not be appreciably affected by net differences between evapotranspiration and rainfall found anywhere in the United States. The spray-runoff approach is intended to minimize the amount of water percolating through the soil to the groundwater and return a substantial fraction of the applied wastewater to surface waters after treatment. The primary fate of the dissolved solids becomes surface waters in much the same manner as the fate of dissolved solids is surface waters for conventional treatment approaches. The concentration of dissolved solids in the water discharged to the surface waters is influenced by the day-to-day balance between evapotranspiration and rainfall, and a minor fraction of the dissolved solids are carried downward with the soil percolate. To summarize the fate of dissolved solids briefly one can say that dissolved solids applied by the irrigation and infiltration approaches end up in groundwater unless the under-drainage is intercepted and diverted to another sink such as a surface stream while the dissolved solids applied by the spray-runoff approach are released directly to surface waters.

Heavy metals and pesticides are two groups of other constituents which are in the limelight at the present time. The presence of both of these groups of other constituents in wastewaters is highly dependent on the industrial contribution to the wastewater, and most of the members of these two groups undergo physical, chemical, or biochemical interactions in the soil. Fragmentary information about the fate of many specific constituents of interest is available, but much remains to be learned about the behavior and hence the fate of trace constituents such as heavy metals and pesticides. Many of the heavy metals are stongly held in the soil by the mechanisms Dr. Erickson has described in the paper he prepared for this Conference. Retention of heavy metals in the soil may be a desirable fate or it may be an undesirable fate. Allaway[14] presents an interesting review on the cycling of trace elements in relation to crop production and human health. He suggests that future agricultural management practices may include control of trace element concentrations in plants through the control of trace element concentrations in soils. The report of the National Technical Advisory Committee on Water Quality Criteria[15] includes a discussion of both heavy metals and pesticides in waters to be used for crop irrigation. This discussion includes a tabular presentation of concentration limits as they pertain to irrigation on various types of soils and for short-term use (up to two decades) versus continuous long-term use. An important factor to remember when dealing with trace constituents such as heavy metals and pesticides is that the total mass of material involved is small, and what would appear to be rather insignificant factors can account for appreciable fractions of the total applied mass.

Summary

The foregoing is a brief summary of the fate of suspended solids, major plant nutrients of environmental concern, and other selected constituents of wastewaters when these wastewaters are applied to the soil by the crop irrigation, infiltration, or spray-runoff approaches to wastewater management. The content of this presentation is intended to give one an insight into the mechanisms involved and the practical aspects involved in the treatment or renovation of wastewater by applying the wastewater to the land. The coverage of the many topics involved is of necessity brief, and one wishing to have a deeper understanding of the subject matter should refer directly to the cited literature and other pertinent reference documents on interactions in the plant-soil environment.

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